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SCALE PATTERN ANALYSIS AS A METHOD FOR IDENTIFYING THE ORIGINS OF SOCKEYE SALMON (*Oncorhynchus nerka*) IN THE WATERS SURROUNDING THE KODIAK ARCHIPELAGO

By

Robert Harvey Conrad

STATE OF ALASKA
Bill Sheffield, Governor
DEPARTMENT OF FISH AND GAME
Don W. Collinsworth, Commissioner
P.O. Box 3-2000, Juneau 99802

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Robert Harvey Conrad

Alaska Department of Fish and Game
Division of Commercial Fisheries
Anchorage, Alaska

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ABSTRACT

The feasibility of using scale patterns and linear discriminant functions to estimate the contributions of sockeye salmon *(Oncorhynchus nerka)* stocks to the salmon fisheries adjacent to Kodiak and Afognak Islands was examined using data collected in 1981. Scale samples from the Afognak, Karluk, Red, Fraser, and Upper Station systems were used to construct classification models for the 1.3 and 2.2 age classes. Samples from Cook Inlet and Chignik were included in the models for the 1.3 age class because previous tagging studies had determined that these stocks were present in the study area, also. The mean classification accuracy of the seven-stock age 1.3 model was 66.1% and the four-stock age 2.2 model 67.3%. The Afognak stock was very distinct from the other stocks and its classification accuracy exceeded 80% in all models. Eight samples of unknown stock composition from fishing districts in the Kodiak Management Area were classified with the age-specific models. Comparison of stock composition estimates and tagging data collected in 1981 indicated several unweired systems could have contributed significantly to the catches in certain fisheries. Although the results of this study were encouraging, further analyses are needed. Future scale pattern analyses in the Kodiak area need to do the following: (1) collect scale samples from the unweired systems so their contributions to the fisheries can be estimated, (2) sample the escapements to the weired systems more intensively to provide samples which can be used to examine the runs for temporal changes in age composition and scale patterns, and (3) collect larger scale samples from the commercial catch to ensure more precise age composition and stock composition estimates.

KEY WORDS: Sockeye salmon, *Oncorhynchus nerka*, stock separation, scale pattern analysis, Kodiak Island.

INTRODUCTION

Effective management of mixed stock salmon fisheries requires knowledge of the temporal and spatial distribution of the contributing stocks. Commercial salmon fisheries in the waters surrounding the Kodiak Archipelago are regulated to minimize the interception of sockeye salmon *(Oncorhynchus nerka)* stocks bound for areas outside the immediate fishing areas, but it is recognized that nearly all the fisheries harvest mixed stocks to some degree. Tagging studies in the Kodiak area have provided information on migration routes and timing of different sockeye salmon stocks through these fisheries (Bevan 1959; Nicholson 1978; Tyler et al. 1984). In some cases, the tagging data have provided estimates on the contribution of selected stocks to specific fisheries. Contribution rates vary with fishing patterns and run strengths, however, and precise management requires annual estimates of these rates. The high cost of mark-recapture experiments precludes their use on an annual basis and a lower cost method, which can be applied annually, is desired. An alternative method of estimating the stock contribution to mixed stock fisheries is scale pattern analysis. The feasibility of using this technique to estimate the contribution of the major sockeye salmon stocks to the fisheries in the Kodiak area is examined in this report.

Description of the Stocks

The Kodiak Management Area is composed of the water surrounding Kodiak and Afognak Islands, including the waters off the Alaska Peninsula extending from Cape Imuya to Cape Douglas (Figure 1). More than thirty different watersheds in the area support spawning populations of sockeye salmon (Manthey et al. 1982). There are five major sockeye salmon systems in the Kodiak area: the Karluk, Red, Upper Station, and Fraser systems on Kodiak Island; and the Afognak system on Afognak Island (Figure 1). Some of the more important secondary sockeye salmon systems are East Uganik, Little River, Horse Marine, Ocean Beach, and Saltery Creek on Kodiak Island; Pauls Lake on Afognak Island; and Kaflia on the Alaska Peninsula. The five major systems accounted for more than 68% of the total sockeye salmon return (catch plus escapement) to the Kodiak management area in 1981 (Table 1).

For the years 1977-1981, the total annual return of sockeye salmon to the Kodiak area averaged 2.2 million. Historically, it appears the Kodiak systems supported much larger runs of sockeye salmon. Catch records provide the best indication of the size of the early runs. Although the early catch records included some salmon from systems outside the Kodiak area and total numbers of fish were estimated from the total case pack, they probably reflect the magnitude of the Kodiak sockeye salmon population. Annual catches exceeding two million fish were common prior to 1910, since then the runs have declined to current levels and, although some stocks have been increasing in abundance recently, present levels are well below historical runs (Figure 2).

The Karluk system was once one of the most productive sockeye salmon systems in Alaska (Burgner et al. 1969) and catches from the Karluk system in the early 1900's usually exceeded 1 million fish. The Karluk catch has not approached that level since 1938 and the total return to the system averaged only 0.53 million for the years 1977-1981. The run of sockeye salmon to the Upper Station system has been depressed, also, averaging only 0.32 million during the same period. The abundance of the Red River run is below historical levels, although it has

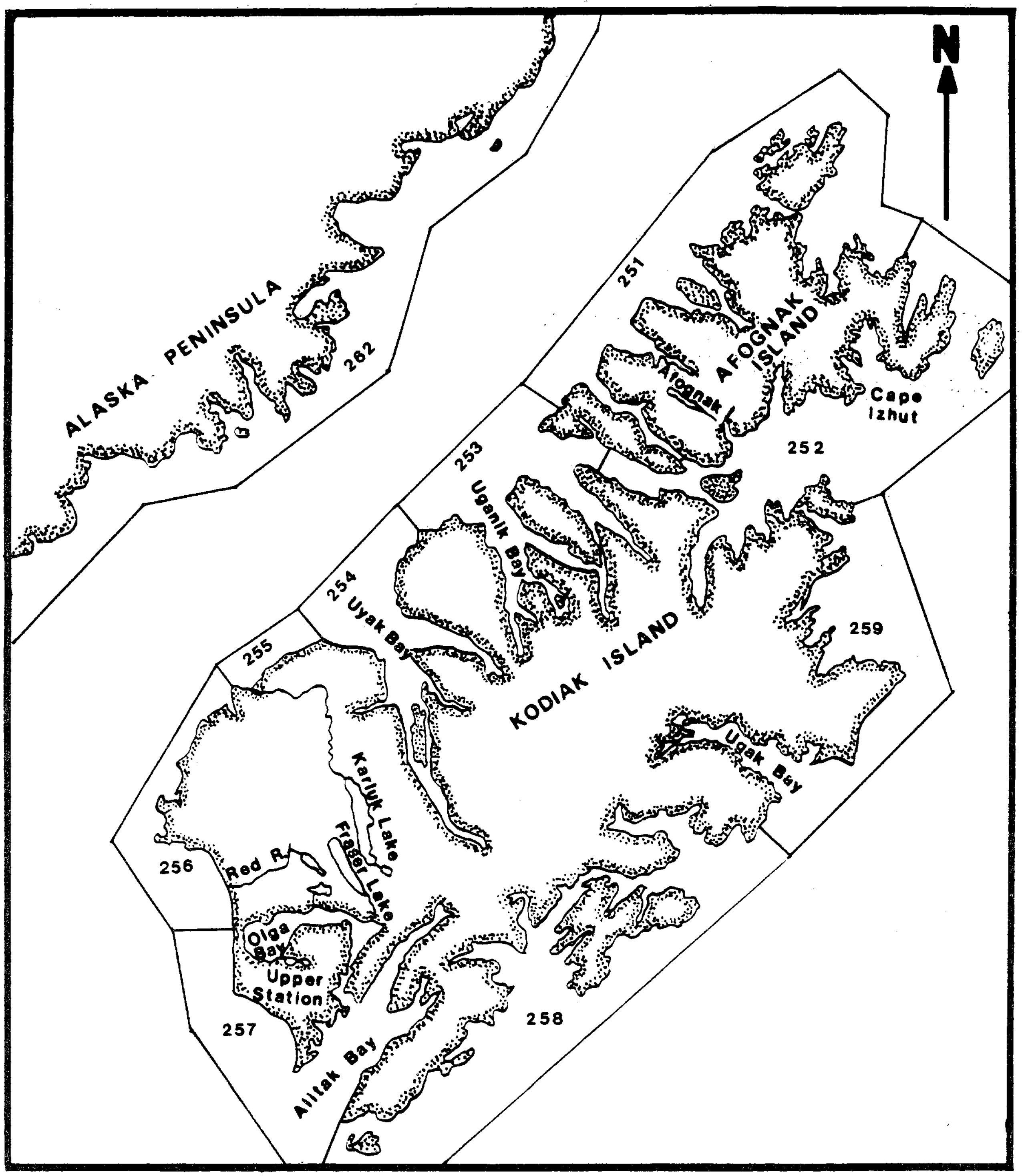

Figure 1. The Kodiak Management Area showing the major commercial fishing statistical areas.

Table 1. Escapements and catches of sockeye salmon by system for the Kodiak Management Area, 1981 [1].

System	Escapement	Catch
Island Systems:		
Afognak	57,267 [2]	
Karluk	222,706	123,259 [3]
Red	279,200	236,545
Fraser	377,716	130,427
Upper Station	181,578	220,190
Major Systems Subtotal	1,118,467	710,421
Pauls Lake	21,811 [4]	
East Uganik	64,000	
Little River	26,500	
Horse Marine	15,000	
Ocean Beach	18,000	
Saltery Creek	43,300	
Other Minor Systems	26,915	
Minor Systems Subtotal	215,526	168,715
Peninsula Systems:		
Kaflia	51,000	
Other systems	6,600	
Peninsula Systems Subtotal	57,600	409,844 [5]
Total All Systems	1,391,593	1,288,980

[1] Source: Manthey et al. 1982.

[2] All major system escapements are weir counts.

[3] Estimated contributions based on historical tagging data.

[4] All minor system escapements estimated by peak aerial surveys.

[5] The majority of the catch taken at Cape Igvak where approximately 80% of the catch is allocated to Chignik.

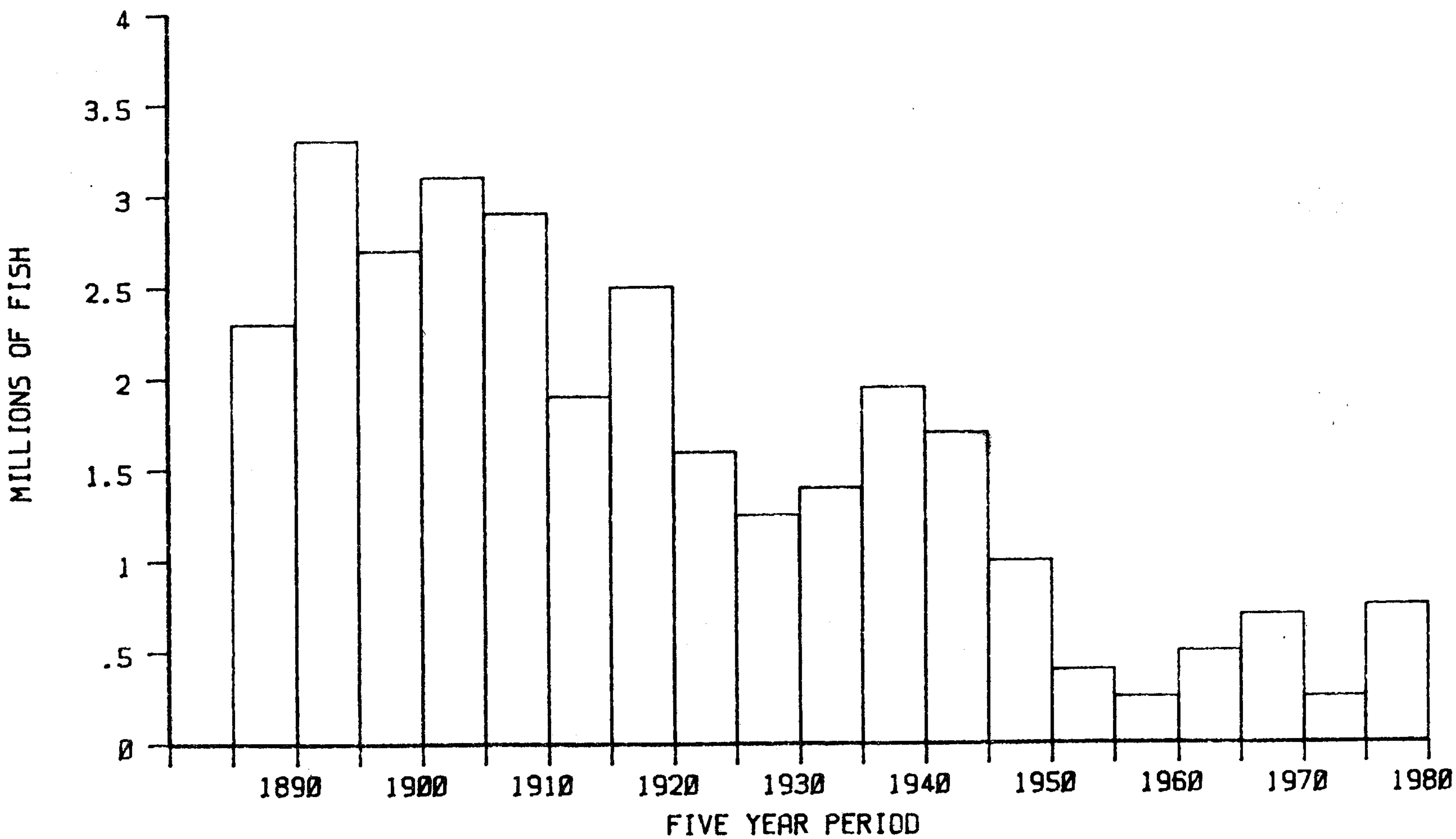

Figure 2. Average commercial catch of sockeye salmon in the Kodiak area by five year periods, 1895-1980.

been increasing in abundance recently (average return of 0.52 million for the years 1977-1981). The run to the Afognak system has increased recently, also. The Fraser Lake sockeye salmon run has grown tremendously in recent years. This stock was artificially introduced in the 1950's by means of egg, fry, and adult transplants and a fish ladder constructed to allow access to the lake. The Fraser Lake run in 1981 was 0.51 million fish (1977-1981 average return of 0.29 million).

Description of the Fishery

Salmon in the Kodiak management area are harvested by purse seine, beach seine, and set gillnet. In 1981, participation in the fishery by percentage of total gear fished was 62.0%, 32.3%, and 5.7% for purse seine, set gillnet, and beach seine, respectively. The areas fished by the two major gear types are shown in Figure 3. The majority of the sockeye salmon catch is taken along the west coast of Kodiak Island from Uganik Bay to Alitak Bay. In 1981, more than 80% of the sockeye salmon catch in the districts around Kodiak and Afognak Islands was from the west coast of Kodiak Island. The sockeye salmon catch by major statistical area is summarized in Table 2. Approximately 50% of the sockeye salmon catch occurred in June with the remaining fish caught in July (30%) and August (19%).

Many sockeye salmon tagging studies have been conducted in the waters adjacent to Kodiak and Afognak Islands. The most comprehensive studies were by Rich and Morton (1929), Bevan (1959), and Tyler et al. (1984). Nicholson (1978) summarized a series of generally small, but geographically comprehensive tagging experiments conducted by the Alaska Department of Fish and Game (ADF&G) from 1961 to 1978. These studies determined that the majority of the salmon passing through Kodiak waters were bound for systems in one of the islands. Minor contributions of stocks from areas outside the Kodiak management area, principally from Cook Inlet and Chignik, were found for some area and time strata. The relative contribution of these non-local stocks varied according to run strengths in the year of tagging. The tagging data indicate that most of the adult sockeye salmon bound for the major systems on Kodiak Island migrate in a southwesterly direction along the west coast of the island. Stocks from the south coast of the island (Upper Station and Fraser) are most vulnerable to interception fisheries as they must migrate past all the fisheries from Uganik Bay to Alitak Bay before reaching Olga Bay.

Scale Pattern Analysis

Scale pattern analysis has become a common procedure for estimating the contribution of different stocks of Pacific salmon to mixed stock salmon fisheries. The ADF&G annually allocates the sockeye salmon catches in Cook Inlet (Cross et al. 1981; 1982; 1983), Chignik (Conrad 1982; 1984a; 1984b), and Lynn Canal (Marshall et al. 1982; McPherson et al. 1983) to the major stocks contributing to these fisheries by analysis of scale patterns. Stock composition estimates for these fisheries are combined with age composition data to allocate the catch by stock and age class. These estimates are combined with escapement run size and age composition data to estimate the total numbers and age composition of each stock.

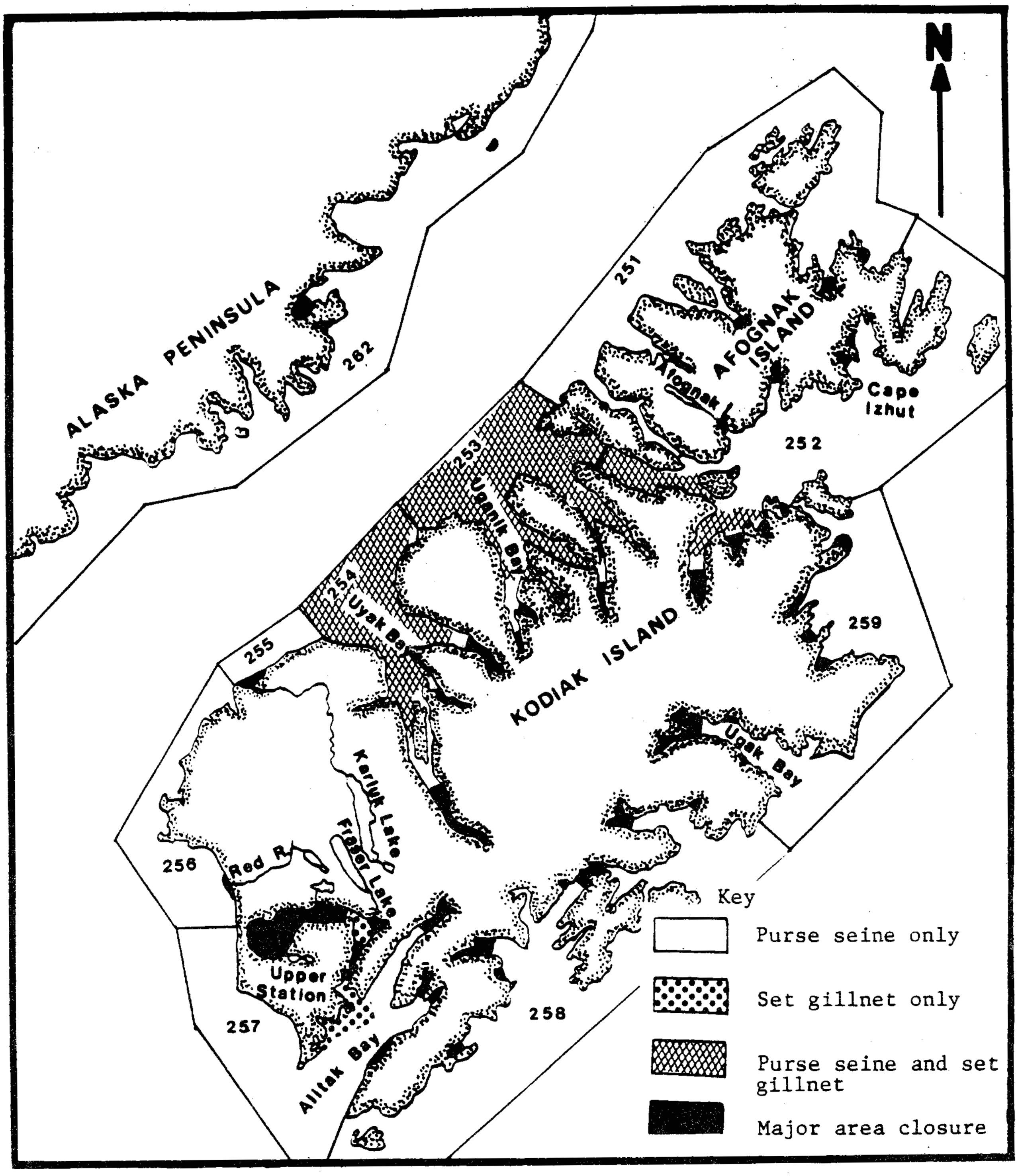

Figure 3. Areas open and closed to commercial salmon fishing by gear type in the Kodiak Management Area, 1981.

Table 2. Catch of sockeye salmon by major statistical area for the Kodiak Management Area, 1981.

Statistical Area	Catch	% Island Areas[1]
251	41,316	4.7
252	47,900	5.4
253	106,033	12.1
254	91,944	10.4
255	346	0.0
256	208,994	23.8
257	346,073	39.4
258	12,956	1.5
259	23,574	2.7
Kodiak-Afognak Area Subtotal	879,136	100.0
262	409,844	
Total	1,288,980	

[1]Percentage of total catch taken from areas contiguous to Kodiak and Afognak Islands.

Scale pattern analysis relies on differences in growth histories among fish from different stocks being reflected in the patterns of circuli on their scales. The degree of differences between the scale patterns of the stocks and how well the features measured on each scale reflect these differences determine the accuracy of the statistical models which identify the stocks. Escapement scale samples are used to construct representative samples (standards) of each stock in the analysis. The circuli patterns on each set of escapement scales are measured and compared using a discriminant analysis technique (e.g., linear discriminant analysis or nearest neighbor analysis) to calculate a set of decision rules which can be used to assign a scale to a stock of origin. The rules are evaluated by estimating their accuracy in classifying scales of known origin to the correct stock. Scales from samples of mixed stock composition can then be classified to estimate the proportion of each stock present.

The feasibility of using scale pattern analysis to allocate commercial catches from the Kodiak area to the major contributing stocks is examined in this report. In 1981, scale samples were collected in conjunction with a sockeye salmon tagging program conducted jointly by ADF&G and the Fisheries Research Institute, University of Washington. These samples and scale samples collected at each of the weir sites on Kodiak and Afognak Islands were used in the analysis. The scale pattern analysis method of allocating the Kodiak stocks was evaluated by comparing the accuracy of the models to those used in other Alaskan systems and comparing the results to those of the tagging study.

METHODS

Escapements: Numbers and Age Composition

Weirs on the five major sockeye salmon systems in the Kodiak Management Area provided daily escapement counts to each system. The weirs began operation in late May and counted the escapements until early August on the Red, Fraser, and Afognak systems and early September on the Upper Station and Karluk systems. Scale samples from the escapements to these systems, collected periodically in conjunction with weir operation, were used to examine the age composition of the escapements and to construct the standards for the discriminant analysis models. Because most of the sample sizes were small, samples collected during specific time periods were pooled to attain numbers sufficient to examine the runs for temporal trends in age composition. Fifteen-day periods were arbitrarily established beginning on 1 June and scale samples collected during each subsequent 15-day period were combined. While pooling allowed a gross examination of the runs for changes in age composition, the sample sizes for all systems but the Fraser are not large enough to warrant allocating the escapements by age class.

Standards for Discriminant Analysis Models

Discriminant analysis models were constructed for each of the major age classes in the Kodiak sockeye salmon runs. Measurements from 200 scales were desired for each standard for an age class and stock. In many cases less than 200 scales for an age class were available and all scales for that age class were measured. For those stocks having more than 200 scales available for an age class, scales for the standards were selected from the escapement samples approximately in proportion to their relative abundance in the run during the period the samples were collected. There are two periods of peak daily abundance in the sockeye salmon escapements to certain Kodiak systems (particularly to the Karluk and Upper Station) and samples from both segments of these runs were included in the standards if available.

The Cook Inlet and Chignik standards were constructed differently as they do not represent discrete stocks but represent the major stocks from an entire region. The Cook Inlet standard consisted of escapement samples from the Kenai, Susitna, Kasilof, Crescent, and Fish Creek systems. The Chignik standard consisted of samples from the Black Lake and Chignik Lake stocks. These regional standards were constructed according to the relative contribution of an age class for a stock to the total return of that age class to all the major stocks in the region. Estimates of the age-specific stock contributions for the Cook Inlet region were from Cross et al. (1983) and for Chignik from Conrad (1982).

Scale Measurement

Impressions of the scales were projected at 100X magnification using equipment similar to that described by Bilton (1970) and later modified by Ryan and Christie (1976). Scale features were measured using a microcomputer-controlled digitizing system. This system projects the scale image on an electronic digitizing surface and the coordinates of the scale feature being measured are entered with a hand-operated free cursor. The coordinates are processed by the microcomputer and the distance between consecutive circuli calculated to the nearest 0.001 inch. Data describing the sample being measured (stock, age, size, sex, etc.) are entered from a keyboard interfaced with the microcomputer. The information describing each sample, a key indicating which zone of the scale a measurement is from, and the linear distance between consecutive circuli are formatted and recorded on a flexible magnetic disk.

All scale measurements were made along an axis approximately perpendicular to the anterior edge of the unsculptured field of the scale and about 20° dorsal or ventral from the anterior-posterior axis (Clutter and Whitsel 1956; Narver 1963). The distance between consecutive circuli in the first freshwater annular zone, the second freshwater annular zone (if present), the freshwater plus growth zone, and the first marine annular zone were measured and recorded by the microcomputer system. Prior to analysis, the detailed scale measurement data were reduced to a more concise format containing the total number of circuli and width of the zones described above and intra-zone distance measurements delineated by specific pairs of circuli within a zone for all zones but freshwater plus growth.

Analytical Procedures

Linear discriminant function (LDF) analysis (Fisher 1936) and the scale measurement data were used to calculate the decision rules for the classification models. Scale characters examined for each analysis included those measured directly from each scale, characters which were linear combinations of those characters, and characters which expressed inter-circuli distances within a zone as a proportion of the total width of the zone (Appendix Table 1). For each classification model, a preliminary examination of the scale characters using group F-statistics and correlation coefficients for each pair of characters reduced the complete set of variables to a more manageable subset of approximately 20. The scale characters selected had either a large F-statistic or were negatively correlated with characters having F-statistics. A large F-statistic results from large between group differences and indicates a variable which may be good for discrimination. Variables selected using these criteria will provide a good subset for constructing a linear discriminant model (Cochran 1964). This subset was then submitted to a forward-stepping procedure to selec the scale characters to be included in the final LDF model. This procedure sequentially enters the variable with the largest partial F-statistic into the model, tests for removal of variables already in the model, recomputes new partial F-statistics after entering or removing a variable, and repeats the process (Enslein et al. 1977). The procedure continues until all variables have been entered into the model or the F-statistic to enter a variable into the model is less than a predefined value.

Using the scale characters selected by the stepwise procedure, a vector of means ($\bar{x}_i$, $i = 1...g$, g = number of stocks) for each stock in the classification model and the pooled variance-covariance matrix (S_p) were calculated. The classification rule was to assign a vector $\mathbf{x}$ of scale measurement data for a single scale to the group for which the quantity,

$$\ln p_i + (\mathbf{x} - \bar{\mathbf{x}}_i/2)' \, \mathbf{S}_p \, \bar{\mathbf{x}}_i, \; i = 1..g$$ [1]

was a maximum (Lachenbruch 1975). The major assumptions underlying linear discriminant analysis are as follows: (1) the groups (stocks) being investigated are discrete and identifiable; (2) the variables used to determine group membership have a multivariate normal distribution in each population; and (3) the variance-covariance matrices for the populations are equal.

The accuracy of each classification model in assigning observations to the correct group was estimated using a leaving-one-out procedure (Lachenbruch 1967). This procedure estimates the classification accuracy by removing one observation from the data used to compute the classification model, calculating new discriminant functions using all remaining observations, and classifying the omitted observation with these functions. This is done for all observations in the standards and the results tallied. This provides nearly unbiased estimates of the classification accuracies of the models.

Scale samples collected during the tagging program and collected from the commercial fishery provided samples of unknown stock composition to be classified by the discriminant models. In studies separating stocks of salmon by their scale patterns the goal is not to determine the origin of individual salmon but to estimate the proportion of different stocks present in an area of intermingling. The origin of each observation from a sample of unknown stock composition was determined using the appropriate LDF and the proportion of each stock present calculated. Worlund and Fredin (1962) noted a set of linear relationships which adjust the proportional estimtes from the mixed sample to account for the classification errors of the assignment rule. Cook and Lord (1978) formulated this approach in matrix notation. Using this notation, let the classification accur-

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[1] p_i is the a priori probability for group $\mathbf{i}$, which for the analyses in this report is equal to the reciprocal of the number of groups in the model.

acies estimated by the leaving-one-out procedure be represented by the matrix $\hat{C}$, where the element C_{ij} is the proportion of the sample from stock j that is classified as stock i. Let $\hat{r}$ be a vector with elements r_1, r_2, ..., where r_i is the proportion of the mixed sample classified as stock i. Then

$$\hat{u} = (\hat{C})^{-1} \hat{r},$$

where each element u_i is the estimate of the proportion of stock i in the sample composed of a mixture of stocks corrected for classification errors. This technique was used for this report. The variances of the elements of $\hat{u}$ were estimated with the formulae proposed by Pella and Robertson (1979) and a 90.0% confidence interval calculated for each estimate.

The elements of $\hat{u}$ can be greater than zero, zero, or less than zero because of the classification matrix correction procedure. Proportional estimates less than or equal to zero for a stock indicate that the stock is not present or present in negligible numbers. Whenever a sample of unknown stock composition was classified and estimates for some stocks were less than or equal to zero, the sample was reclassified with a model which did not include those stocks.

RESULTS

Daily Escapements and Age Compositions

The daily escapements of sockeye salmon to each of the major systems in the Kodiak area are shown in Figure 4. For all systems but the Fraser, there were two discrete periods of large daily escapements, the first occurring in June and the second in July or August (although the presence of a second period in the Afognak system is questionable). The commercial fishery affects the daily escapement pattern but it is not responsible for these distinct periods of increased daily abundance. The seasonal distribution of the daily escapements to these systems suggested two segments in the runs with distinctly different timing. The earliest arriving segment of the runs occurred in the first 15 days of June. Timing of the second segment of the runs varied between systems with the Red River system having the earliest timing, in mid-July, and the Karluk system the latest, in late August.

In the Kodiak escapement samples, only the 1.3[1] and 2.2 age classes were present in numbers sufficient to construct standards for classification models. The contribution of the 1.3 and 2.2 age classes to the pooled escapement samples is shown in Figure 4, also. More than half of the escapement samples to each system belonged to these two age classes (Appendix Tables 2-6). Although there were changes in the age composition during the season for all systems, sample sizes were not large enough to determine whether the differences were significant. For the Red River system, the two periods of large daily abundance had different estimated age compositions. No such differences occurred in the Afognak and Upper Station systems. The second period of increased daily abundance was not sampled for the Karluk, unfortunately.

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[1] European formula: Number of freshwater annuli, decimal point, number of marine annuli. The total age is the sum of these two numbers plus one.

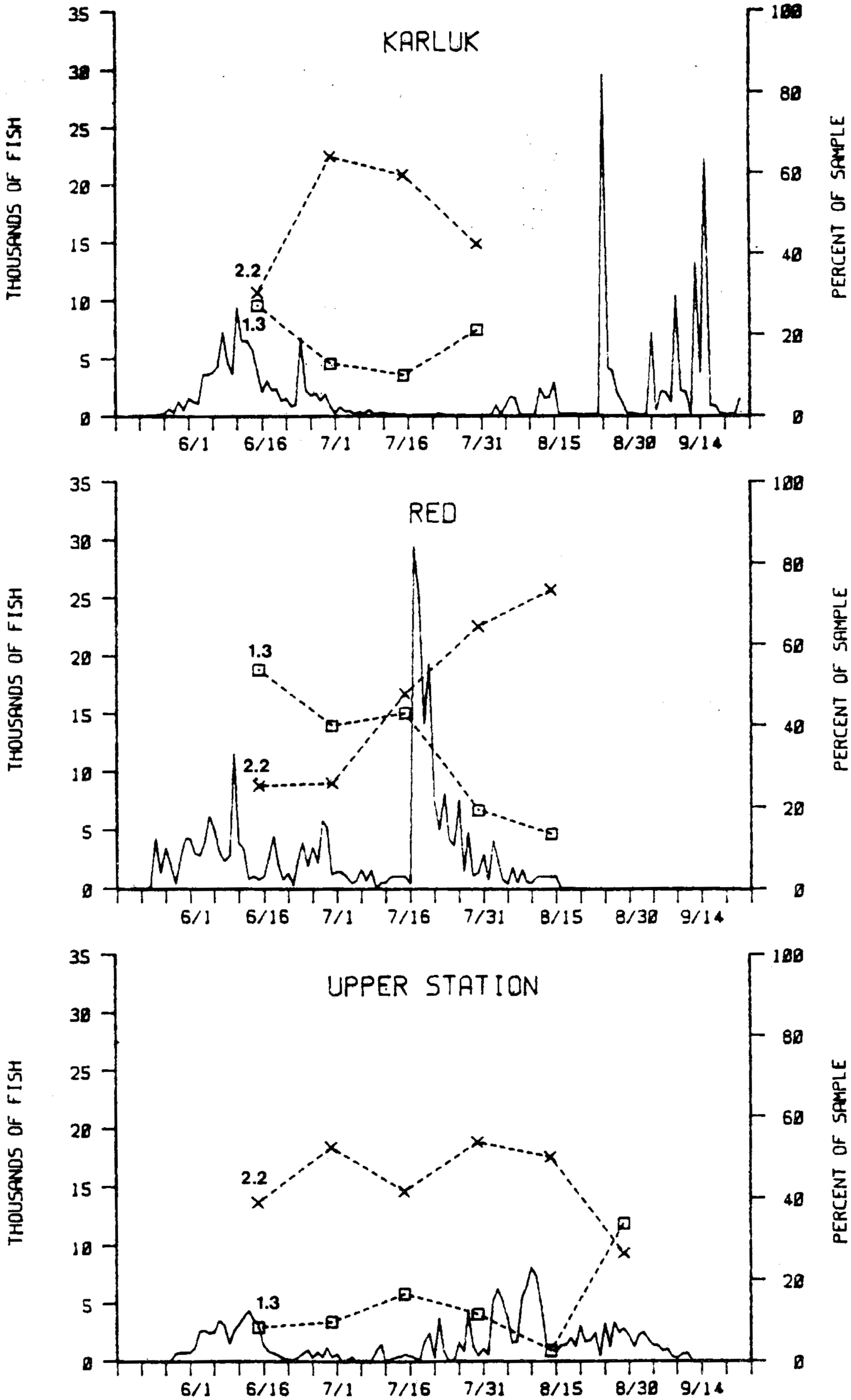
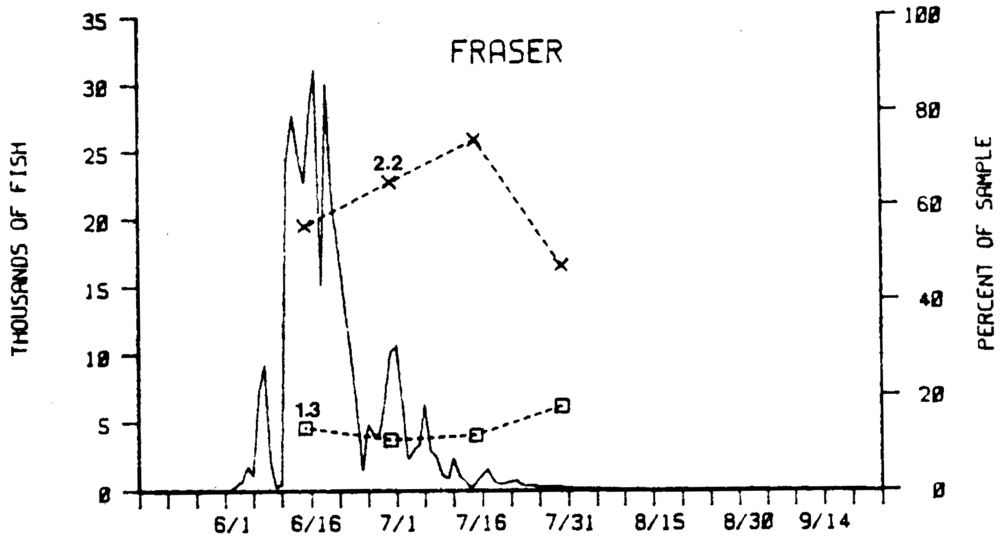


Figure 4. Daily escapements of sockeye salmon and contribution of the 1.3 and 2.2 age classes to escapement samples by period for the major Kodiak systems.



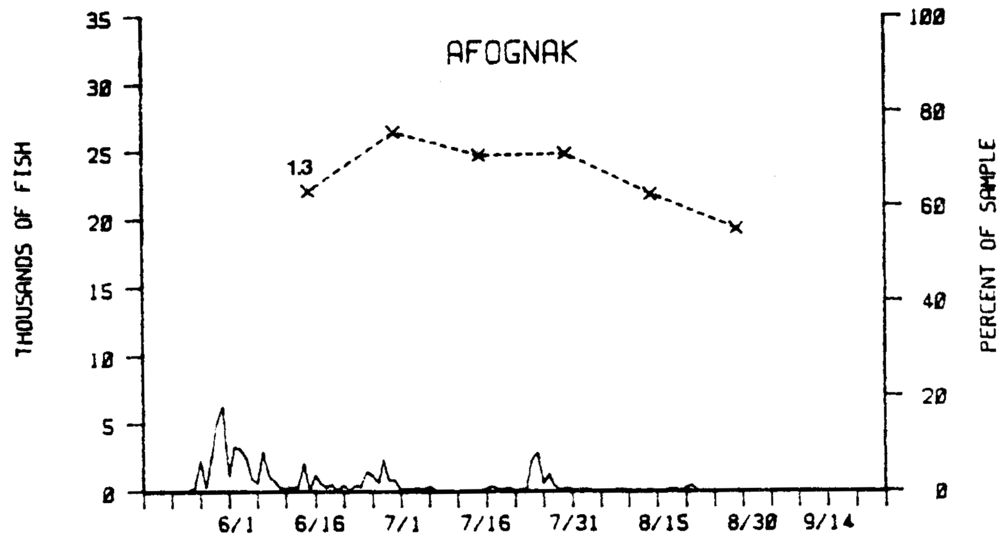


Figure 4. Daily escapements of sockeye salmon and contribution of the 1.3 and 2.2 age classes to escapement samples by period for the major Kodiak systems (continued).

The linear discriminant classification models for the 1.3 age class included the Cook Inlet and Chignik regional standards when appropriate. In 1981, age 1.3 sockeye salmon were the dominant age class in the stocks returning to these areas. Approximately 70% of the total Cook Inlet return and 48% of the total Chignik return were allocated to this age class. The age 2.2 classification models were constructed with standards from the Karluk, Red, Upper Station, and Fraser systems. No age 2.2 fish were found in the Afognak samples and the contribution of that age class to the Cook Inlet and Chignik regions was minor with allocations of 6% and 4% of the total return, respectively.

Summary Statistics for Scale Variables

Summary statistics for the basic measurements of scale growth for the 1.3 and 2.2 age classes are presented in Tables 3 and 4. The stepwise procedure consistently selected certain variables for the ages 1.3 and 2.2 linear discriminant classification models. These variables had large between group differences and were usually some of the first variables entered into the models. Frequency histograms comparing the distribution of some of these scale variables for the stocks are presented in Figure 5-10. For the 1.3 age class, the Afognak stock had the smallest zone of freshwater growth of all stocks (Figures 5-7). The freshwater zone of the Cook Inlet and Chignik stocks was intermediate between the Afognak stock and the other Kodiak stocks. The Fraser system had the largest zone of freshwater growth. Differences among stocks for the first marine zone are not as distinct and there is much overlap among stocks (Figure 8). For the four age 2.2 stocks, the Fraser and Upper Station stocks had the largest freshwater scale growth zone and the smallest first marine zone (Figures 9 and 10).

Classification Models

Classification matrices for the linear discriminant models calculated for the 1.3 and 2.2 age classes were calculated. The mean classification accuracy of the age 1.3 model including all Kodiak stocks, Cook Inlet, and Chignik was 66.1% (Table 5). Mean classification accuracies of the other age 1.3 models ranged from 73.0% for a six-stock model to 91.7% for a three-stock model. Afognak scale patterns were very distinct and the classificastion accuracy for the Afognak stock is very high with a mean accuracy of 89.2% for all models which included it. The Cook Inlet and Chignik stocks were generally distinct from the Kodiak stocks and most classification errors for these two stocks were between themselves. For all models, the mean misclassification error rate between fish of Cook Inlet or Chignik origin and the Kodiak stocks was less than 20%. The Kodiak stocks which were most difficult to discriminate were the Red River and Upper Station systems. The Upper Station had the lowest mean classification accuracy for the models it was in, 58.2%.

The mean classification accuracy of the age 2.2 model with the four Kodiak Island stocks was 67.3% (Table 6). Two three-stock models were required to classify age 2.2 fishery samples, a Karluk-Red-Fraser model which had a mean classification accuracy of 75.2% and a Karluk-Upper Station-Fraser model which had a mean classification accuracy of 81.8%. Similar to the age 1.3 classification models, the Red River and Upper Station systems were most difficult to discriminate in the age 2.2 model with all four Kodiak Island stocks.

Table 3. Mean ($\bar{X}$) and standard error (SE) of basic scale variables for the 1.3 age class (scale width measurements in 0.01's of inches at 100X).

Scale Variable[1]		Chignik	Cook In.	Afognak	Karluk	Red	Up. Station	Fraser
				Stock				
Number circuli first FW zone	$\bar{X}$	9.6	11.5	7.2	13.8	12.0	11.5	15.5
	SE	(0.134)	(0.212)	(0.078)	(0.338)	(0.172)	(0.359)	(0.193)
Width first FW zone	$\bar{X}$	107.9	133.6	92.9	179.1	138.9	147.0	190.8
	SE	(1.464)	(2.477)	(0.856)	(4.221)	(1.979)	(3.979)	(2.422)
Number circuli FW plus growth	$\bar{X}$	3.8	3.2	3.5	3.2	5.4	5.9	6.3
	SE	(0.109)	(0.123)	(0.163)	(0.238)	(0.111)	(0.290)	(0.184)
Width FW plus growth zone	$\bar{X}$	41.9	33.9	45.5	37.4	62.3	70.3	74.9
	SE	(1.232)	(1.389)	(1.961)	(2.722)	(1.281)	(3.549)	(1.965)
Number circuli first marine zone	$\bar{X}$	24.8	24.4	24.1	24.6	22.2	19.6	20.0
	SE	(0.178)	(0.197)	(0.199)	(0.352)	(0.191)	(0.367)	(0.266)
Width first marine zone	$\bar{X}$	399.7	407.5	382.8	430.1	361.1	324.2	337.4
	SE	(2.792)	(2.964)	(3.477)	(5.567)	(4.057)	(5.739)	(4.276)

[1] FW = freshwater.

Table 4. Mean ($\bar{X}$) and standard error (SE) of basic scale variables for the 2.2 age class (zone width measurements in 0.01's of inches at 100X).

Scale Variable[1]		Karluk	Red	Up. Station	Fraser
Number circuli first FW zone	$\bar{X}$	10.6	11.1	11.4	10.9
	SE	(0.231)	(0.138)	(0.122)	(0.217)
Width first FW zone	$\bar{X}$	127.3	121.3	123.0	126.3
	SE	(2.204)	(1.454)	(1.287)	(2.154)
Number circuli second FW zone	$\bar{X}$	9.5	10.3	11.7	13.0
	SE	(0.177)	(0.146)	(0.115)	(0.216)
Width second FW zone	$\bar{X}$	82.9	96.6	116.9	122.4
	SE	(1.776)	(1.569)	(1.146)	(2.001)
Number circuli FW plus growth	$\bar{X}$	1.9	1.7	2.5	3.6
	SE	(0.096)	(0.074)	(0.086)	(0.122)
Width FW plus growth zone	$\bar{X}$	19.9	17.8	27.8	33.8
	SE	(0.962)	(0.958)	(1.011)	(1.104)
Number circuli first marine zone	$\bar{X}$	25.7	24.8	24.4	23.1
	SE	(0.246)	(0.199)	(0.195)	(0.267)
Width first marine zone	$\bar{X}$	417.3	391.6	383.8	355.5
	SE	(4.094)	(3.522)	(3.072)	(4.756)

The columns Karluk, Red, Up. Station and Fraser are grouped under the heading "Stock".

[1] FW = freshwater.

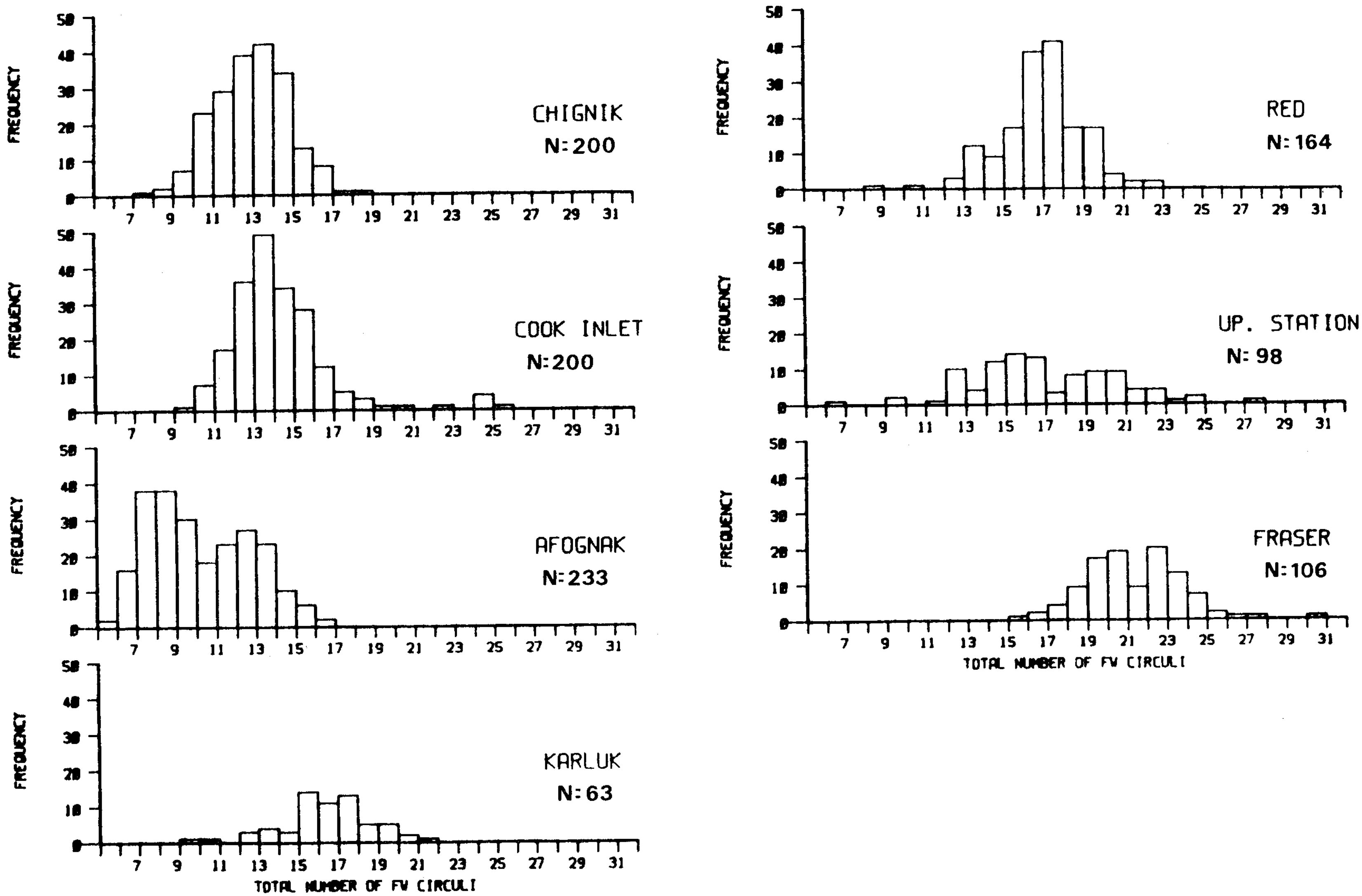


Figure 5. Frequency histograms of the total number of circuli in the freshwater zone for age 1.3 sockeye salmon.

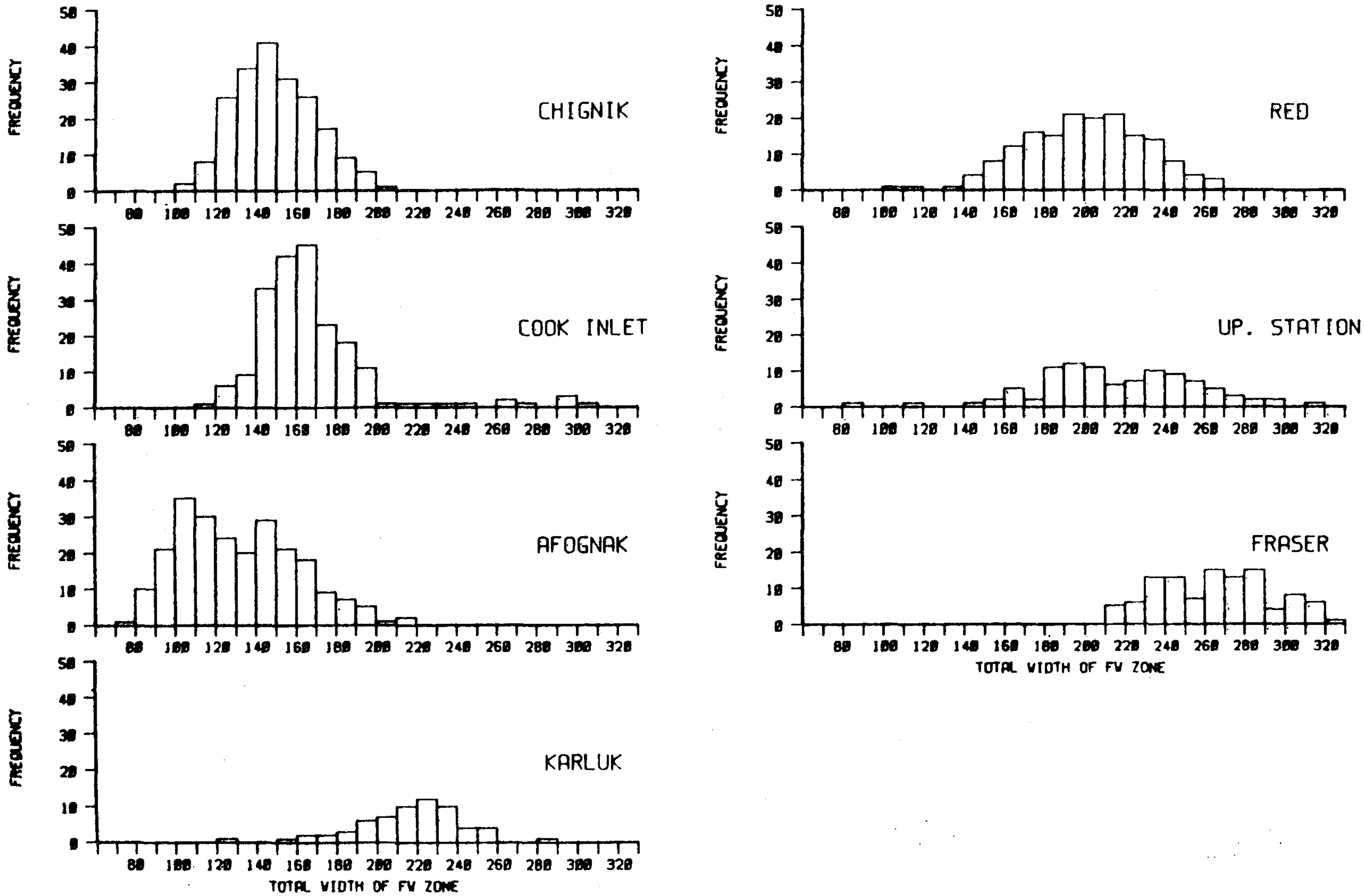


Figure 6. Frequency histograms of the total width of the freshwater zone for age 1.3 sockeye salmon.

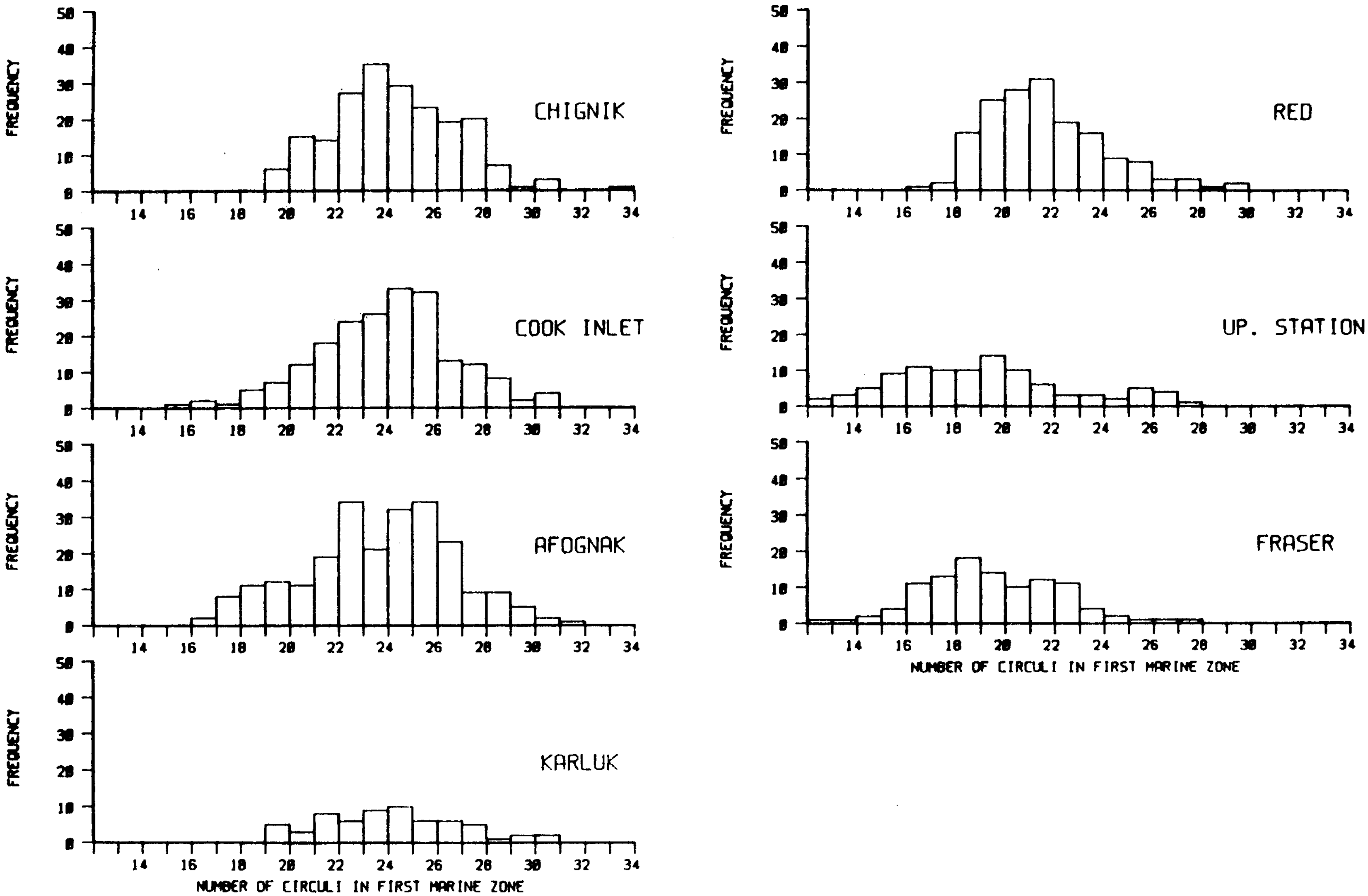


Figure 7. Frequency histograms of the total number of circuli in the first marine zone for age 1.3 sockeye salmon.

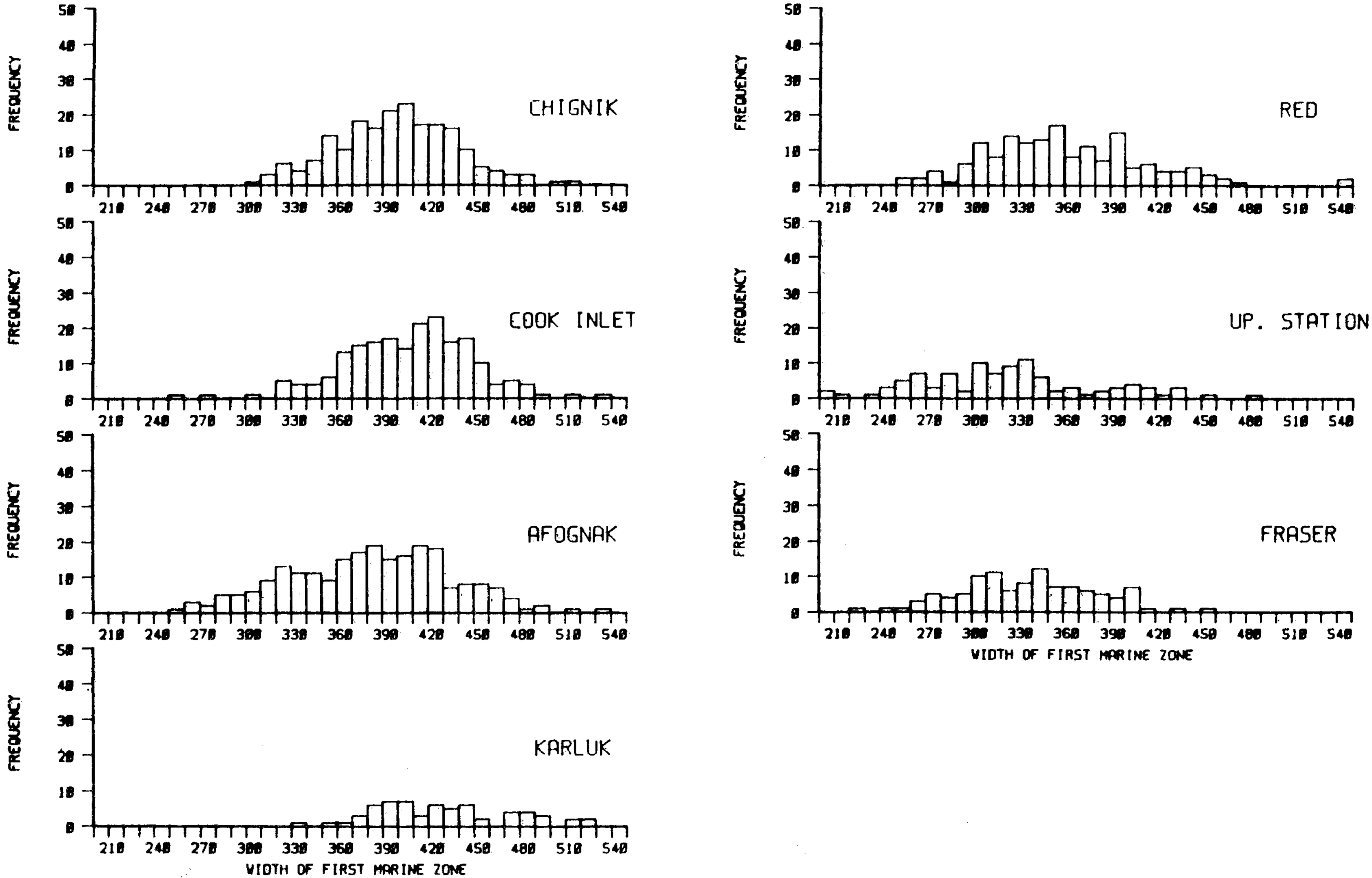


Figure 8. Frequency histograms of the total width of the first marine zone for age 1.3 sockeye salmon.

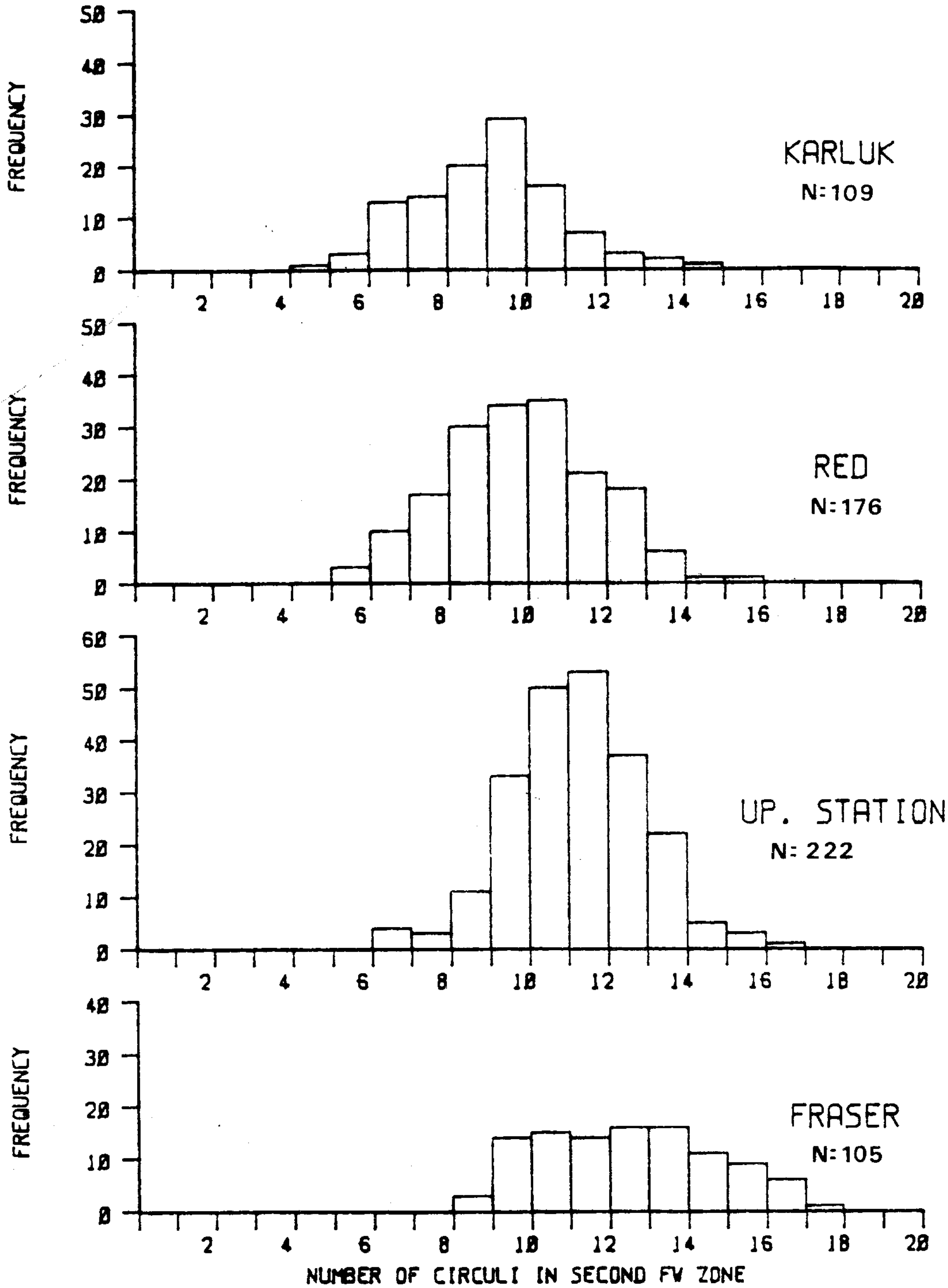


Figure 9. Frequency histograms of the number of circuli in the second freshwater zone for age 2.2 sockeye salmon.

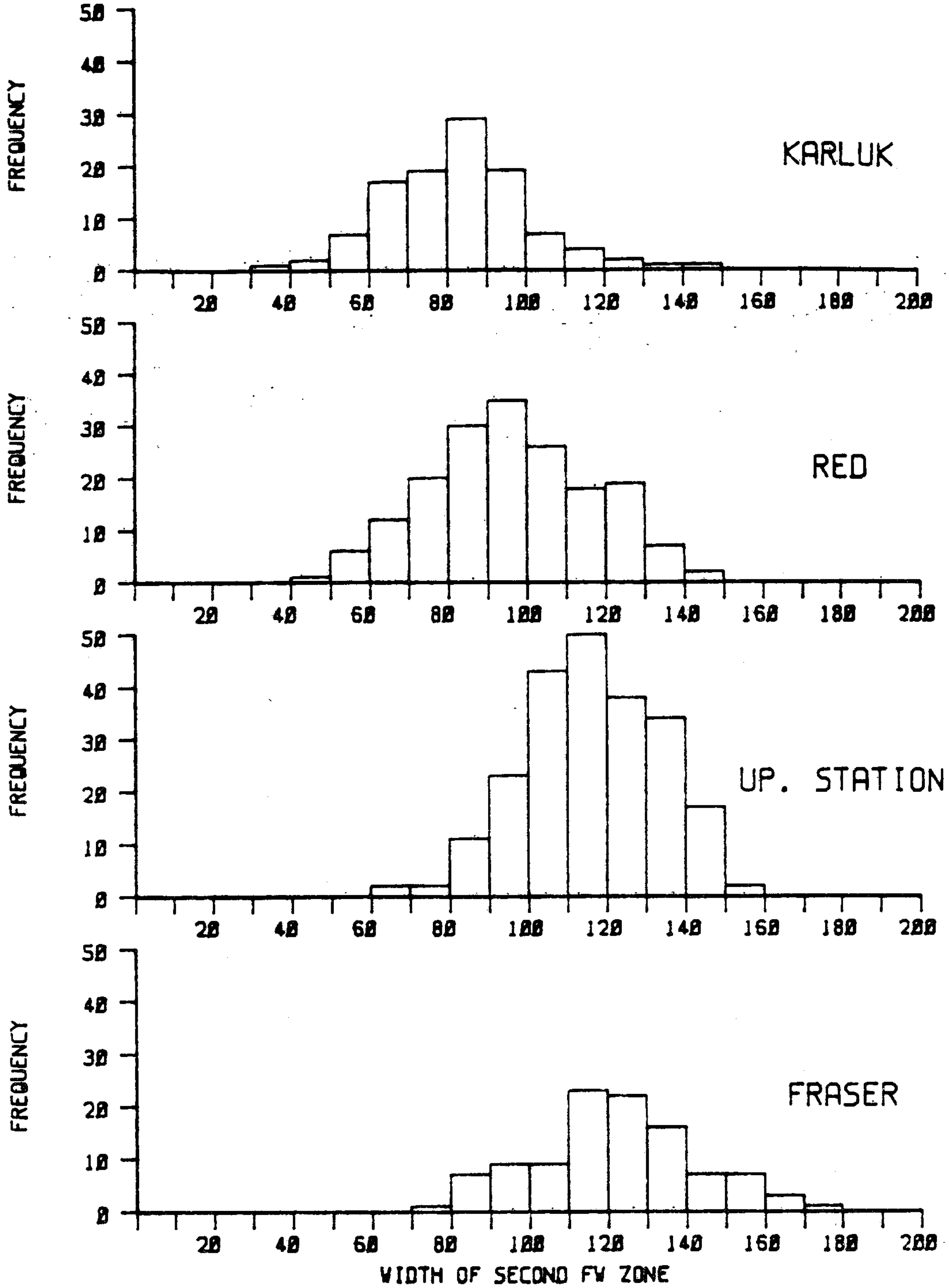


Figure 10. Frequency histograms of the width of the second freshwater zone for age 2.2 sockeye salmon.

Table 5. Classification matrices for the linear discriminant models used to classify age 1.3 sockeye salmon.

Variables in model: 66, 17, 71, 2, 88, 4, 70, 92, 65, 28, 20[1]

Actual Stock of Origin	Sample Size	Classified Stock of Origin						
		Cook In.	Chignik	Afognak	Fraser	Karluk	Up. Station	Red
Cook In.	200	0.585	0.165	0.055	0.040	0.075	0.020	0.060
Chignik	200	0.165	0.680	0.095	0.000	0.010	0.000	0.050
Afognak	233	0.034	0.090	0.811	0.000	0.000	0.026	0.039
Fraser	106	0.000	0.000	0.000	0.726	0.075	0.123	0.075
Karluk	63	0.079	0.016	0.016	0.032	0.730	0.000	0.127
Up. Station	98	0.031	0.041	0.061	0.153	0.082	0.469	0.163
Red	164	0.073	0.049	0.018	0.030	0.110	0.091	0.628

mean proportion correctly classified = 0.661

Variables in model: 66, 17, 2, 91, 74, 4, 65, 28, 70, 71, 61

Actual Stock of Origin	Sample Size	Classified Stock of Origin					
		Cook In.	Chignik	Afognak	Fraser	Karluk	Red
Cook In.	200	0.610	0.175	0.045	0.040	0.060	0.070
Chignik	200	0.150	0.700	0.095	0.000	0.020	0.035
Afognak	233	0.026	0.077	0.833	0.000	0.000	0.064
Fraser	106	0.000	0.000	0.000	0.811	0.066	0.123
Karluk	63	0.063	0.016	0.032	0.079	0.698	0.111
Red	164	0.079	0.030	0.018	0.037	0.091	0.744

mean proportion correctly classified = 0.733

Variables in model: 17, 2, 88, 4, 74, 70, 92, 65, 28, 14, 109

Actual Stock of Origin	Sample Size	Classified Stock of Origin					
		Chignik	Afognak	Fraser	Karluk	Up. Station	Red
Chignik	200	0.810	0.090	0.000	0.020	0.005	0.075
Afognak	233	0.099	0.863	0.000	0.000	0.021	0.017
Fraser	106	0.000	0.000	0.783	0.047	0.094	0.075
Karluk	63	0.048	0.032	0.048	0.698	0.048	0.127
Up. Station	98	0.061	0.061	0.143	0.071	0.531	0.133
Red	164	0.061	0.030	0.030	0.104	0.079	0.695

mean proportion correctly classified = 0.730

[1] Refer to Appendix Table 1.

-Continued-

Table 5. Classification matrices for the linear discriminant models used to classify age 1.3 sockeye salmon (continued).

Variables in model: 17, 2, 91, 4, 74, 65, 70, 71, 28, 14

Actual Stock of Origin	Sample Size	Classified Stock of Origin				
		Chignik	Afognak	Fraser	Karluk	Red
Chignik	200	0.790	0.105	0.000	0.020	0.085
Afognak	233	0.107	0.880	0.000	0.000	0.013
Fraser	106	0.000	0.000	0.821	0.066	0.113
Karluk	63	0.032	0.063	0.127	0.651	0.127
Red	164	0.067	0.030	0.061	0.073	0.768

mean proportion correctly classified = 0.782

Variables in model: 66, 17, 2, 88, 71, 70, 4, 92, 20, 65, 109

Actual Stock of Origin	Sample Size	Classified Stock of Origin				
		Chignik	Afognak	Fraser	Karluk	Up. Station
Chignik	200	0.850	0.110	0.000	0.025	0.015
Afognak	233	0.094	0.880	0.000	0.004	0.021
Fraser	106	0.000	0.000	0.821	0.047	0.132
Karluk	63	0.063	0.048	0.032	0.825	0.032
Up. Station	98	0.092	0.061	0.153	0.092	0.602

mean proportion correctly classified = 0.796

Variables in model: 17, 71, 14, 7, 104, 2, 65, 28, 109

Actual Stock of Origin	Sample Size	Classified Stock of Origin				
		Afognak	Fraser	Karluk	Up. Station	Red
Afognak	233	0.953	0.000	0.000	0.013	0.034
Fraser	106	0.000	0.745	0.047	0.113	0.094
Karluk	63	0.032	0.079	0.698	0.048	0.143
Up. Station	98	0.061	0.133	0.092	0.592	0.122
Red	164	0.030	0.024	0.110	0.091	0.744

mean proportion correctly classified = 0.746

-Continued-

Table 5. Classification matrices for the linear discriminant models used to classify age 1.3 sockeye salmon (continued).

Variables in model: 66, 16, 92, 70, 65, 73, 88, 4, 71, 109

Actual Stock of Origin	Sample Size	Classified Stock of Origin			
		Chignik	Afognak	Up. Station	Red
Chignik	200	0.825	0.095	0.005	0.075
Afognak	233	0.090	0.880	0.017	0.013
Up. Station	98	0.061	0.051	0.714	0.173
Red	164	0.067	0.037	0.098	0.799

mean proportion correctly classified = 0.804

Variables in model: 14, 65, 17, 7, 71, 2, 28, 109

Actual Stock of Origin	Sample Size	Classified Stock of Origin			
		Afognak	Fraser	Karluk	Red
Afognak	233	0.957	0.000	0.000	0.043
Fraser	106	0.000	0.830	0.047	0.123
Karluk	63	0.048	0.111	0.698	0.143
Red	164	0.037	0.043	0.110	0.811

mean proportion correctly classified = 0.824

Variables in model: 14, 65, 17, 7, 71

Actual Stock of Origin	Sample Size	Classified Stock of Origin		
		Afognak	Fraser	Red
Afognak	233	0.974	0.000	0.026
Fraser	106	0.000	0.887	0.113
Red	164	0.043	0.067	0.890

mean proportion correctly classified = 0.917

Table 6. Classification matrices for the linear discriminant models used to classify age 2.2 sockeye salmon.

Variables in model: 32, 61, 111, 27, 31, 67, 66, 46, 1, 44, 55[1]

Actual Stock of Origin	Sample Size	Classified Stock of Origin			
		Fraser	Karluk	Up. Station	Red
Fraser	105	0.762	0.019	0.152	0.067
Karluk	109	0.009	0.743	0.055	0.193
Up. Station	222	0.117	0.041	0.658	0.185
Red	176	0.034	0.119	0.318	0.528

mean proportion correctly classified = 0.673

Variables in model: 61, 44, 111, 27, 31, 67, 65, 29

Actual Stock of Origin	Sample Size	Classified Stock of Origin		
		Fraser	Karluk	Red
Fraser	105	0.771	0.067	0.162
Karluk	109	0.018	0.734	0.248
Red	176	0.102	0.148	0.750

mean proportion correctly classified = 0.752

Variables in model: 32, 111, 61, 57, 27, 66, 2, 46, 55

Actual Stock of Origin	Sample Size	Classified Stock of Origin		
		Fraser	Karluk	Up. Station
Fraser	105	0.800	0.048	0.152
Karluk	109	0.037	0.844	0.119
Up. Station	222	0.117	0.072	0.811

mean proportion correctly classified = 0.818

[1] Refer to Appendix Table 1.

Classification of Fishery Samples

Eight scale samples of unknown stock composition collected from the commercial fishing districts of the Kodiak Management Area were analysed. Some scale samples collected within a few days of each other in the same area were pooled to increase sample sizes. The age composition of the fishery samples is summarized in Table 7. The 1.3 and 2.2 age classes were the most abundant in the samples, when combined they accounted for between 64% and 95% of the scales in the unknown samples. Both the 1.3 and 2.2 age classes were analysed in all samples but the Ugak Bay sample on 18 June which did not have sufficient numbers of age 2.2 salmon for analysis (Table 8).

For the 1.3 age class, fish of Cook Inlet origin were found only in the Uganik Bay sample collected in early June (Table 8). Low incidences (less than 20%) of Chignik fish were found in the Uganik Bay (6 and 7 June) and Uyak Bay (29 June) samples. High incidences (greater than 40%) of Chignik stocks were estimated for the Ugak Bay and Cape Izhut samples. The Afognak stock was present in all eight fishery samples, although the estimated proportion was greater than 30% only in the Uganik Bay (15 and 18 June) sample. The majority of the two Uyak Bay samples were assigned to the Karluk stock. In the two Alitak Bay samples, the predominate stock was the Fraser.

The Fraser stock was present in all seven samples for the 2.2 age class. The estimated contribution of the Fraser stock to the two Alitak Bay samples was greater than 75% and it was the predominant stock in the Uganik Bay (15 and 18 June) and Uyak Bay (29 June) samples, also. Except for the mid-June Alitak Bay sample, the Karluk stock was present in all age 2.2 samples. The estimated percentage of the Karluk stock in these samples was moderate (5%-30%) with the exception on the Cape Izhut sample, where 72.0% of the sample was allocated to the Karluk. Upper Station stock was found in moderate levels (less than 25%) in the Uganik Bay (15 and 18 June), both Alitak Bay, and the Uyak Bay (29 June) samples. Red River stock was present in moderate levels, also, except for a 51% contribution to the Uganik Bay sample in early June.

DISCUSSION

Comparison with Other Scale Pattern Analysis Models

The accuracies of the linear discriminate models used to classify the 1.3 and 2.2 age classes were comparable or better than models commonly used in other areas of the state (see Introduction for references). Cook Inlet is the only other area of the state where large (five or more stocks) models are applied to sockeye salmon stock identification problems. The accuracies of the five, six, and seven stock models for the 1.3 age class were superior to the accuracies usually attained for the five stock Cook Inlet models by 5% to 15%. Classification accuracies for the 2.2 age clsss models were not as high as those for the age 1.3 models. The classification accuracies were still comparable with models of similar size used in allocation problems elsewhere. The lower mean classification accuracies for the age 2.2 models are unusual when compared to the results of other scale pattern analyses. Typically, for an analysis which includes fish of both 1 and 2 freshwater ages, the mean classification accuracies of the models

Table 7. Age composition by percent of sample for sockeye salmon collected from commercial fishing districts in the Kodiak Management Area during 1981.

Location/ Stat. Area	Sample Date(s)	Sample Size	Age Class[1] 0.3	1.1	1.2	1.3	2.2	2.3	3.2	Other
Uganik Bay 253	6/6, 6/7	240	0.4	0.0	20.4	22.9	41.3	15.0	0.0	0.0
	6/15, 6/18	150	0.0	0.0	19.3	50.7	22.7	7.3	0.0	0.0
Alitak Bay 257	6/13, 6/14	432	0.0	1.2	6.2	17.4	64.8	10.4	0.0	0.0
	6/28	293	0.0	0.3	15.4	34.5	41.0	7.9	0.3	0.6
Ugak Bay 259	6/18	161	0.6	0.0	1.9	95.0	0.6	1.9	0.0	0.0
Uyak Bay 254	6/29	120	0.0	0.0	15.8	41.7	35.0	7.5	0.0	0.0
	7/7, 7/11	196	0.0	0.0	11.7	30.1	47.0	10.2	0.0	1.0
Cape Izhut 252	6/21	249	0.0	0.4	22.5	48.6	22.9	4.8	0.0	0.8

[1] European formula: Number of freshwater annuli, decimal point, number of marine annuli. The total age is the sum of these two numbers plus one.

Table 8. Estimated stock composition and 90.0% confidence interval for ages 1.3 and 2.2 sockeye salmon collected from commercial fishing districts in the Kodiak Management Area during 1981.

Location/ Sample Date(s)	Age	Sample Size	Stock: Cook In.	Chignik	Afognak	Karluk	Red	Up. Station	Fraser
Uganik Bay 6/6, 6/7	1.3	56	0.201	0.189	0.300	0.251	0.052		0.007
	C. I.		-0.110, 0.511	-0.094, 0.473	0.060, 0.540	-0.007, 0.510	-0.146, 0.250		-0.099, 0.114
	2.2	83				0.235	0.510		0.255
	C. I.					0.049, 0.421	0.276, 0.744		0.097, 0.413
Uganik Bay 6/15, 6/18	1.3	65			0.847	0.055	0.052		0.046
	C. I.				0.714, 0.981	-0.045, 0.155	-0.076, 0.180		-0.036, 0.127
	2.2	26				0.278	0.064	0.188	0.470
	C. I.					-0.041, 0.597	-0.453, 0.582	-0.321, 0.697	0.113, 0.827
Alitak Bay 6/13, 6,14	1.3	71			0.010		0.109		0.881
	C. I.				-0.022, 0.042		-0.040, 0.259		0.736, 1.026
	2.2	97				0.00		0.160	0.840
	C. I.					-0.078, 0.077		-0.013, 0.334	0.662, 1.017
Alitak Bay 6/28	1.3	93			0.099	0.115	0.193	0.236	0.358
	C. I.				-0.005, 0.203	-0.058, 0.287	-0.010, 0.397	-0.013, 0.484	0.140, 0.577
	2.2	144				0.038		0.214	0.748
	C. I.					-0.039, 0.114		0.063, 0.364	0.594, 0.902
Ugak Bay 6/18	1.3	100		0.541	0.167		0.202	0.091	
	C. I.			0.366, 0.715	0.033, 0.300		0.049, 0.356	-0.021, 0.202	

-Continued-

Table 8. Estimated stock composition and 90.0% confidence interval for ages 1.3 and 2.2 sockeye salmon collected from commercial fishing districts in the Kodiak Management Area during 1981 (continued).

Location/ Sample Date(s)	Age	Sample Size	Stock Cook In.	Chignik	Afognak	Karluk	Red	Up. Station	Fraser
Uyak Bay 6/29	1.3	46		0.114	0.176	0.391		0.150	0.169
	C. I.			-0.082, 0.311	-0.027, 0.380	0.131, 0.651		-0.116, 0.416	-0.049, 0.386
	2.2	35				0.228	0.141	0.092	0.539
	C. I.					-0.036, 0.492	-0.322, 0.603	-0.341, 0.526	0.224, 0.854
Uyak Bay 7/7, 7/11	1.3	55			0.202	0.391	0.174	0.133	0.100
	C. I.				0.030, 0.374	0.094, 0.689	-0.089, 0.438	-0.119, 0.385	-0.100, 0.300
	2.2	76				0.280	0.444		0.276
	C. I.					0.082, 0.477	0.202, 0.687		0.111, 0.441
Cape Izhut 6/21	1.3	99		0.478	0.233		0.181	0.108	
	C. I.			0.305, 0.652	0.090, 0.376		0.032, 0.330	-0.010, 0.225	
	2.2	60				0.720	0.243		0.038
	C. I.					0.458, 0.981	-0.046, 0.531		-0.069, 0.144

for the 2 freshwater age fish have a higher mean classification accuracy than the 1 freshwater age models because of the additional information available to separate the stocks in the second year of freshwater growth.

Comparison with the Tagging Results

Ideally, there would be a direct comparison of the scale pattern analysis results with the tagging results. Scale pattern analysis provides a point estimate of the proportional contribution of a stock to an area and time stratum and a confidence interval for that estimate. The tagging results, however, are qualitative and can be used only as an indication of which stocks are present in a stratum, but cannot be used to estimate the contribution of the stocks. Several strict assumptions must be fulfilled before the relative abundance of each stock at the time of tagging can be estimated from its relative contribution to the total recovery of tags (Seber 1973). During tagging all stocks must have been equally vulnerable to capture so that for a given area and time the number of fish tagged from each stock is in proportion to their relative abundance. Secondly, post-tagging mortality and tag loss must be similar for all stocks. For the Kodiak tagging, this is probably not true as mortality and tag loss are time dependent processes and the greater the time between release and recovery the greater the mortality and tag loss in absolute numbers (Brannian 1983). This causes the more distant recovery areas, Cook Inlet and Chignik, to be under represented in the total recoveries in comparison to the Kodiak stocks because they have lost more fish through mortality and tag loss. Another important assumption involves tag recovery and reporting. To estimate relative stock strength from recovery data it must be assumed that the tag recovery rate is equal or known for all recovery areas. For recovery rates to be equal, similar percentages of each stock must be surveyed for recoveries or a tagged fish must have a similar probability of recapture in each area. If recovery rates are unequal but known, adjustments can be made to the number of recoveries by area to make them comparable. This would be very difficult for the Kodiak tagging because the majority of the recoveries for Kodiak stocks were from weir observations while nearly all of the Cook Inlet and Chignik recoveries were made in the commercial fishery.

Another problem with a direct comparison of the scale pattern analysis and tagging results is that the scale pattern stock composition estimates are age-specific but the age composition of the recovered tags from an area is not known. If the tag recoveries from a particular tagging release were primarily of an age class other than the 1.3 or 2.2, a comparison of the results would not be appropriate.

Stock Contribution by Strata

The stock composition indicated by the results of the scale pattern analysis (SPA) and the tagging study of Tyler et al. (1984) will be discussed by each area of sampling. There were only four scale samples collected simultaneously with tagging and these will be examined in detail. The other scale samples analyzed were collected in the commercial fishery and have no tagging data for direct comparison, these will be discussed in general terms.

Uganik Bay:

Analysis of scale patterns of the early June samples show that the Cook Inlet, Chignik, and all Kodiak stocks but the Upper Station were present in moderate numbers. The most abundant of these stocks were the Karluk, Red, and Fraser

(Table 8). Tagging results indicate that the Karluk and Fraser stocks were most abundant in the area with minor contributions of the Red, Upper Station, and Afognak stocks (Table 9). There were no tag recoveries from Cook Inlet or Chignik.

The Uganik Bay scale samples in mid-June have no tagging data for comparison. More than 80% of the 1.3 age class was allocated to the Afognak stock by scale pattern analysis. Because there was not a large escapement to this system, and more than half of the escapement had passed the weir by the sample date, the dominance of the Afognak stock in the Uganik area is very unusual. This may be due to the presence of stocks which were not included in the classification model, probably those from East Uganik River and Little River (Figure 11). The peak escapement estimate for the East Uganik River is large (64,000) and was made on an aerial survey approximately 1 week after the Uganik Bay sample was collected. If the scale patterns of sockeye salmon from the East Uganik River were similar to the patterns of Afognak River fish, the discriminant procedure would classify them as Afognak fish. Unfortunately, no scales were collected from the East Uganik River in 1981. In future analyses, scales from the East Uganik River and other unweired systems should be collected so that their contributions to the catch can be estimated.

Alitak Bay:

Both scale pattern analysis and tagging indicated that the majority of the two Alitak Bay samples were of Fraser origin. The SPA of the mid-June scale samples estimated that more than 80% of the samples were from the Fraser with minor contributions of the Upper Station and Red stocks (Table 8). One percent was allocated to the Afognak, but this was probably because of the presence of miscellaneous minor stocks in the area. Most of the tag recoveries from the mid-June release were in the Fraser with ancillary recoveries in the Upper Station and Chignik (Table 9).

The Fraser stock dominated the late June sample, also, although not to the degree of the earlier sample. The SPA assigned most of the sample to the Fraser and approximately 20% to the Upper Station for both age classes. Minor contributions were estimated for the Karluk, Red, and Afognak stocks. The tagging results indicated that the Fraser, Red, and Chignik stocks were present. The tagging results are inconclusive, however, because approximately 70% of the recovered tags were taken in the Alitak Bay-Olga Bay commercial fishery. The minor contribution of the Afognak stock to the 1.3 age class (9.9%) estimated by SPA was probably a result of stocks in the area which were not accounted for by the classification models.

Uyak Bay:

There were no tagging data in Uyak Bay which to compare the SPA results. Uyak Bay is near the Karluk River and one would expect to find significant numbers of the Karluk stock present. Both Uyak Bay samples were collected between the two periods of peak daily sockeye salmon escapements to the Karluk (Figure 4) which could attenuate the contribution of the Karluk stock. All Kodiak stocks and the Chignik stock were estimated to be present in the late June sample. The Karluk and Fraser stocks were the most abundant and the contributions of the other stocks less than 20%. Sample sizes for both age classes were small, which decreases the degree of confidence in these estimates.

Table 9. Recovery locations of tags released on sockeye salmon in the Kodiak Management Area in 1981[1].

Location/ Sample Date(s)	Tags Released	Tags Recovered	Stock							
			Cook In.	Chignik	Afognak	Karluk	Red	Up. Station	Fraser	Other
Uganik Bay 6/6, 6/7	315	136	0	0	3	61	5	4	24	39
Alitak Bay 6/13	366	244	0	3	0	0	0	6	91	144
Alitak Bay 6/28	345	164	0	8	0	0	3	0	12	141
Cape Izhut 6/21	294	49	5	4	5	2	1	0	1	31

[1] Source: Tyler et al. 1984.

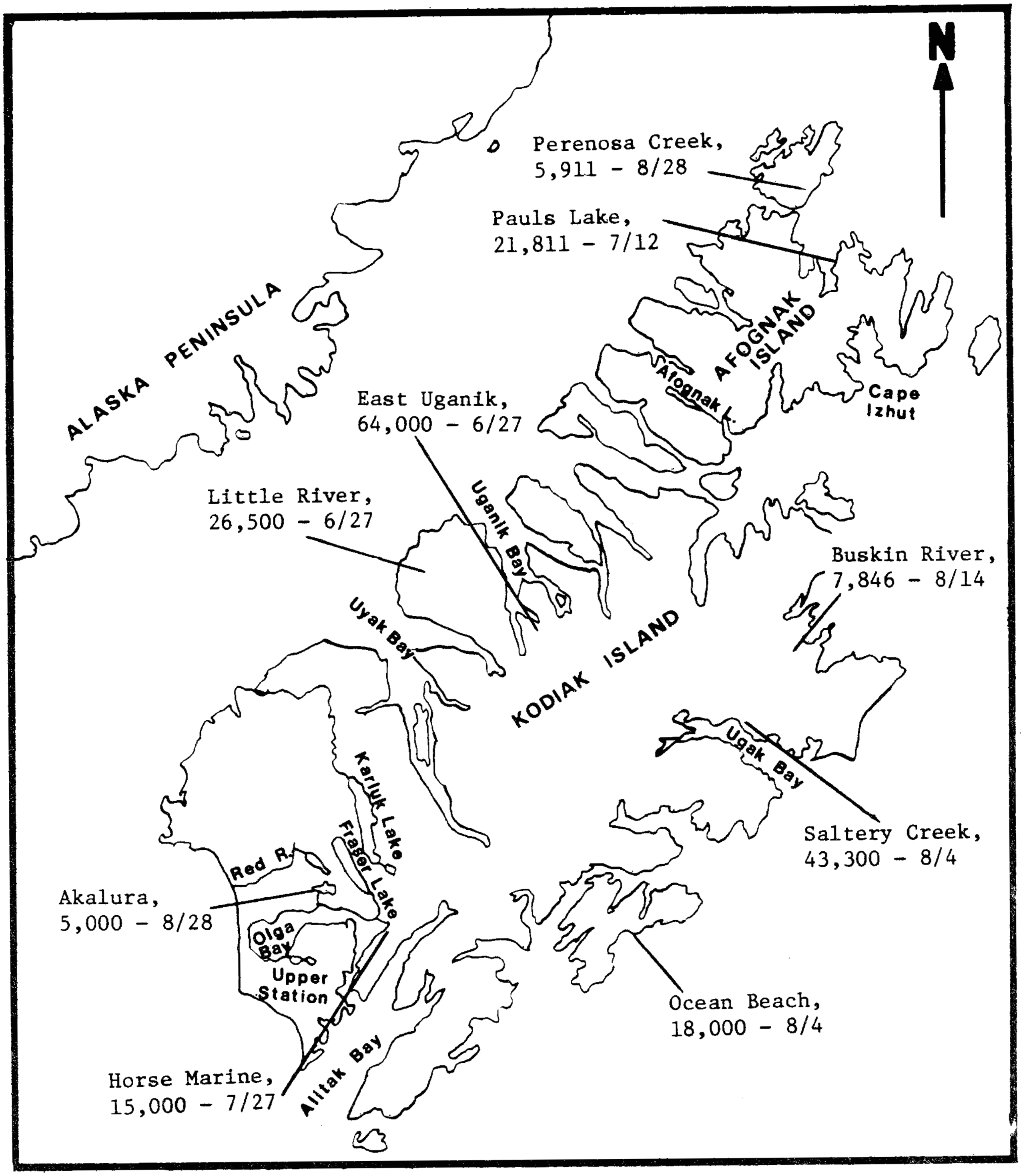


Figure 11. Unweired sockeye salmon systems on Kodiak and Afognak Islands with peak aerial survey estimates of escapements and date of peak survey in 1981.

All five Kodiak stocks were estimated to be present in the early July sample from Uyak Bay. The most abundant stocks were the Karluk and Red, and contributions of the other stocks were minor. The only minor system in the immediate vicinity of the sample area which might have influenced the results was the Little River (Figure 11).

Ugak Bay:

No tagging was conducted in the Ugak Bay area. The scale pattern analysis indicates a high proportion of the Chignik stock in the area with minor contributions of the Afognak, Red, and Upper Station stocks. The classification results for this sample are questionable because all eastside stocks are minor and were not represented in the models. One unweired system which is a tributary to Ugak Bay, Saltery Creek (Figure 11), had a peak aerial survey escapement estimate of 43,000. This system was probably present in large numbers in the Ugak Bay sample, but because it was not included in the classification models all fish from it would be mis-assigned to other stocks.

Cape Izhut:

Chignik and all five Kodiak stocks were estimated to be present in the Cape Izhut sample by analysis of scale patterns. For the 1.3 age class, the Chignik stock was found to be most abundant followed by the Afognak, Red, and Upper Station (Table 8). The majority (72%) of the 2.2 age class was allocated to the Karluk, with minor contributions by the Red and Fraser stocks. The tagging data indicate that the Cook Inlet, Chignik, Afognak, Karluk, Red, and Fraser stocks were all present in the area (Table 9). The Cook Inlet, Chignik, and Afognak stocks were the most abundant of these.

Summary:

It is difficult to draw conclusions from the comparison of the scale pattern analysis and the tagging results. For the two Alitak Bay samples, the SPA results and the tagging results correspond reasonably well. The SPA results for the other areas are questionable when compared to the tagging data and general knowledge about stock distribution. This is probably due to the presence of stocks from unweired systems in the sampling areas. There was minimal tag recovery effort on these systems so their contribution to the tagging samples is unknown. Although these systems are considered minor, some of the systems support large runs of sockeye salmon and could contribute substantial numbers to certain area and time strata. The sampling areas most susceptible to the influence of the stocks from unweired systems are Uganik Bay, Ugak Bay, and Cape Izhut. A major assumption of discriminant function analysis is that all groups which may be present in the samples of unknown composition are represented in the classification models. If groups (stocks) not represented in the classification models are present in the samples being classified, the individuals from those groups are classified as one of the other groups in the model. If the individuals from the unrepresented groups are rare, the classification results are not severely effected. If there are large numbers of the unrepresented groups present, the classification estimates will be meaningless.

It is interesting to note that most of the questionable results of the scale pattern analyses are the presence of the Afognak stock in areas it is not expected. The Afognak stock had a much smaller freshwater scale growth zone than the other Kodiak stocks (Table 3, Figures 5-6) and was very distinct from the other Kodiak stocks in the classification models. If freshwater scale growth in the unweired systems is similar to the Afognak system, i.e., less than that of the other Kodiak Island systems, fish from these systems would be allocated to the Afognak stock.

CONCLUSION

The results of the 1981 scale pattern analysis study for sockeye salmon in the Kodiak Management Area are encouraging. The high mean classification accuracies of the linear discriminant models for the 1.3 and 2.2 age classes indicate that, at least in 1981, the major sockeye salmon stocks in the Kodiak area had distinctive scale patterns which could be used as a basis for identifying the stocks. Differences in scale patterns are presumed persistent and the classification accuracy in other years should be similar, but additional analyses are needed. There appear to be some major discrepancies between the stock composition estimated by analysis of scale patterns and the tagging results of Tyler et al. (1984) for some samples from the fishery area. Possible explanations for these discrepancies were discussed in the previous section, the primary one being the presence of stocks in the sampling area not represented in the discriminant models. The results of the scale pattern analysis cannot be evaluated solely by comparison to the tagging data, however. A major problem with the tagging study was the failure to adequately survey unweired systems for tag recoveries, therefore, the contribution of these stocks to different time and area strata could not be estimated.

One of the greatest benefits from the 1981 scale pattern study is that it indicates the potential problems with an intensive scale pattern analysis of sockeye salmon in the Kodiak Management Area. Future scale pattern studies in the area should be designed to resolve three issues listed below:

1) Scale samples from the unweired systems were not collected. Although many of these systems are considered minor, the aerial survey escapement estimates suggest they may contribute substantial numbers to some area and time strata. Scale samples from the more important unweired systems need to be collected so that their scale patterns can be compared to those of the major systems. The systems which should be sampled will depend on run strength in the year of sampling, but the historical data indicate that East Uganik River and Saltery Creek should be sampled annually.

2) Scale collection at the weired systems was not adequate and needs to be increased on all systems but the Fraser. Effort should be directed at taking large, time-specific samples throughout the duration of the run. Sample sizes of approximately 625 scales[1] collected during 1 or 2 day

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[1] A sample of 625 fish would allow the age composition for a time and area strata to be estimated within ± 5.0% for each age class and for the sample to have the true age composition 90.0% of the time. This sampling level assumes five major age groups and accounts for the presence of regenerated scales. Source: Memo by Dr. D.R. Bernard to J.H. Clark and S.L. Marshall dated 27 January 1983.

periods distributed throughout the runs are needed to examine the runs for temporal changes in age composition. It is important that samples be collected during each period of increased daily escapements for those systems having more than a single mode in their daily escapement pattern. If both the early and late arriving segments of the runs are sampled, the scale patterns of each segment can be compared to see if there are significant differences between the segments. This may indicate that time-specific classification models are required, one for early season and one for late season.

3) Sample sizes from the fishery area were small. Much larger scale samples need to be collected from the commercial fishery area. The sample sizes suggested for the escapement samples would be appropriate for these samples, also. These sample sizes would result in more precise estimates of the age composition of the commercial catch and ensure that at least 100 scales were available for an age class for scale pattern analysis.

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APPENDICES

Appendix Table 1. Scale characters screened for linear discriminant function analyses.

Variable	1st FW Annular Zone
1	Number circuli in 1st FW a. z. (NC1FW)
2	Width of 1st FW a.z. (S1FW)
3 (16)	Distance, scale focus (C0) to circulus 2 (C2)
4	Distance, C0-C4
5 (18)	Distance, C0-C6
6	Distance, C0-C8
7 (20)	Distance, C2-C4
8	Distance, C2-C6
9 (22)	Distance, C2-C8
10	Distance, C4-C6
11 (24)	Distance, C4-C8
12	Distance, C(NC1FW-4)-End of 1st FW a. z. (E1FW)
13 (26)	Distance, C(NC1FW-2)-E1FW
14	Distance, C2-E1FW
15	Distance, C4-E1FW
16-26	Relative widths, (variables 3-13)/S1FW
27	Average interval between circuli, S1FW/NC1FW
28	Number circuli in 1st 3/4 of zone
29	Maximum distance between 2 consecutive circuli
30	Relative width, variable 29/S1FW

Variable	2nd FW Annular Zone
31	Number circuli in 2nd FW a. z. (NC2FW)
32	Width of 2nd FW a.z. (S2FW)
33 (46)	Distance, E1FW to circulus 2 (C2)
34	Distance, E1FW-C4
35 (48)	Distance, E1FW-C6
36	Distance, E1FW-C8
37 (50)	Distance, C2-C4
38	Distance, C2-C6
39 (52)	Distance, C2-C8
40	Distance, C4-C6
41 (54)	Distance, C4-C8
42	Distance, C(NC2FW-4)-E2FW
43 (56)	Distance, C(NC2FW-2)-E2FW
44	Distance, C2-E2FW
45	Distance, C4-E2FW
46-56	Relative widths, (variables 33-43)/S2FW
57	Average interval between circuli, S2FW/NC2FW

Appendix Table 1. Scale characters screened for linear discriminant function analyses (continued).

Variable	1st FW Annular Zone
58	Number of circuli in 1st 3/4 of zone
59	Maximum distance between 2 consecutive circuli
60	Relative width, variable 63/S2FW
	FW Plus Growth
61	Number circuli of FW plus growth
62	Width of FW plus growth zone
	All FW Zones
63	Total number FW annular circuli (NC1FW+NC2FW)
64	Total width FW annular zone (S1FW+S2FW)
65	Total number FW circuli (NC1FW+NC2FW+NCPG)
66	Total width FW zone (S1FW+S2FW+SPGZ)
67	Relative width, S1FW/(S1FW+S2FW+SPGZ)
68	Relative width, SPGZ/(S1FW+S2FW+SPGZ)
69	Relative width, S2FW/(S1FW+S2FW+SPGZ)

Variable	1st Ocean Annular Zone
70	Number circuli in 1st marine a.z. (NC1OZ)
71	Width of 1st marine a.z. (S1OZ)
72 (90)	Distance, End of FW growth (EFW) to circulus 3 (C3)
73	Distance, EFW to C6
74 (92)	Distance, EFW to C9
75	Distance, EFW to C12
76 (94)	Distance, EFW to C15
77	Distance, C3-C6
78 (96)	Distance, C3-C9
79	Distance, C3-C12
80 (98)	Distance, C3-C15
81	Distance, C6-C9
82 (100)	Distance, C6-C12
83	Distance, C6-C15
84 (102)	Distance, C9-C15
85	Distance, C(NC1OZ-6)-E1OZ
86 (104)	Distance, C(NC1OZ-3)-E1OZ
87	Distance, C3-E1OZ
88	Distance, C9-E1OZ
89	Distance, C15-E1OZ
90-104	Relative widths, (variables 73-86)/S1OZ

Appendix Table 1. Scale characters screened for linear discriminant function analyses (continued).

Variable	1st Ocean Annular Zone
105	Average interval between circuli, S1OZ/NC1OZ
106	Number of circuli in 1st half of zone
107	Maximum distance between 2 consecutive circuli
108	Relative width, variable 107/S1OZ
	All Ocean Zones
109	Width 2nd ocean zone, if present (S2OZ)
110	Width 3rd ocean zone, if present (S3OZ)
111	Total width ocean zones, (S1OZ+S2OZ+S3OZ)
112	Relative width, S1OZ/(S1OZ+S2OZ+S3OZ)
113	Relative width, S2OZ/(S1OZ+S2OZ+S3OZ)

Appendix Table 2. Age composition of sockeye salmon scale samples, pooled by 15 day period, from the Afognak.

Sample Dates		Age Class 1.1	1.2	2.2	3.2	1.3	2.3	1.4	Other	Total
6/ 1 - 6/15	Numbers	1	30	0	0	53	0	0	0	84
	Percent	1.2	35.7	0.0	0.0	63.1	0.0	0.0	0.0	
6/16 - 6/30	Numbers	9	4	0	0	43	0	1	0	57
	Percent	15.8	7.0	0.0	0.0	75.4	0.0	1.8	0.0	
7/ 1 - 7/15	Numbers	18	8	0	0	62	0	0	0	88
	Percent	20.4	9.1	0.0	0.0	70.5	0.0	0.0	0.0	
7/16 - 7/30	Numbers	21	27	0	0	122	1	0	1	172
	Percent	12.2	15.7	0.0	0.0	70.9	.6	0.0	.6	
7/31 - 8/14	Numbers	23	19	0	0	71	0	1	0	114
	Percent	20.2	16.6	0.0	0.0	62.3	0.0	.9	0.0	
8/15 - 8/29	Numbers	1	8	0	0	11	0	0	0	20
	Percent	5.0	40.0	0.0	0.0	55.0	0.0	0.0	0.0	
Totals	Numbers	73	96	0	0	362	1	2	1	535
	Percent	13.6	17.9	0.0	0.0	67.7	.2	.4	.2	

Appendix Table 3. Age composition of sockeye salmon scale samples, pooled by 15 day period, from the Karluk.

Sample Dates		Age Class 1.1	1.2	2.2	3.2	1.3	2.3	1.4	Other	Total
6/ 1 - 6/15	Numbers	0	12	28	5	25	19	0	3	92
	Percent	0.0	13.0	30.4	5.4	27.2	20.7	0.0	3.3	
6/16 - 6/30	Numbers	0	12	89	5	18	14	0	1	139
	Percent	0.0	8.6	64.0	3.6	13.0	10.1	0.0	.7	
7/ 1 - 7/15	Numbers	1	15	83	0	14	27	0	0	140
	Percent	.7	10.7	59.3	0.0	10.0	19.3	0.0	0.0	
7/16 - 7/30	Numbers	0	3	22	0	11	16	0	0	52
	Percent	0.0	5.8	42.3	0.0	21.1	30.8	0.0	0.0	
Totals	Numbers	1	42	222	10	68	76	0	4	423
	Percent	.2	9.9	52.5	2.4	16.1	18.0	0.0	.9	

Appendix Table 4. Age composition of sockeye salmon scale samples, pooled by 15 day period, from the Red River.

Sample Dates		Age Class 1.1	1.2	2.2	3.2	1.3	2.3	1.4	Other	Total
6/ 1 - 6/15	Numbers	1	5	42	0	90	29	0	1	168
	Percent	.6	3.0	25.0	0.0	53.6	17.2	0.0	.6	
6/16 - 6/30	Numbers	0	5	44	0	68	51	0	3	171
	Percent	0.0	2.9	25.7	0.0	39.8	29.8	0.0	1.8	
7/ 1 - 7/15	Numbers	0	2	20	0	18	2	0	0	42
	Percent	0.0	4.8	47.6	0.0	42.8	4.8	0.0	0.0	
7/16 - 7/30	Numbers	0	0	74	0	22	19	0	0	115
	Percent	0.0	0.0	64.4	0.0	19.1	16.5	0.0	0.0	
7/31 - 8/14	Numbers	0	1	55	0	10	9	0	0	75
	Percent	0.0	1.4	73.3	0.0	13.3	12.0	0.0	0.0	
Totals	Numbers	1	13	235	0	208	110	0	4	571
	Percent	.2	2.3	41.1	0.0	36.4	19.3	0.0	.7	

Appendix Table 5. Age composition of sockeye salmon scale samples, pooled by 15 day period, from the Upper Station.

Sample Dates		Age Class 1.1	1.2	2.2	3.2	1.3	2.3	1.4	Other	Total
6/ 1 - 6/15	Numbers	0	41	42	0	9	15	0	1	108
	Percent	0.0	38.0	38.9	0.0	8.3	13.9	0.0	.9	
6/16 - 6/30	Numbers	0	44	75	0	14	10	0	0	143
	Percent	0.0	30.8	52.4	0.0	9.8	7.0	0.0	0.0	
7/ 1 - 7/15	Numbers	0	33	35	0	14	1	0	1	84
	Percent	0.0	39.3	41.7	0.0	16.6	1.2	0.0	1.2	
7/16 - 7/30	Numbers	0	48	79	0	17	3	0	0	147
	Percent	0.0	32.7	53.7	0.0	11.6	2.0	0.0	0.0	
7/31 - 8/14	Numbers	0	46	57	0	3	7	0	1	114
	Percent	0.0	40.4	50.0	0.0	2.6	6.1	0.0	.9	
8/15 - 9/ 1	Numbers	0	31	41	0	52	30	0	0	154
	Percent	0.0	20.1	26.6	0.0	33.8	19.5	0.0	0.0	
Totals	Numbers	0	243	329	0	109	66	0	3	750
	Percent	0.0	32.4	43.9	0.0	14.5	8.8	0.0	.4	

Appendix Table 6. Age composition of sockeye salmon scale samples, pooled by 15 day period, from the Fraser.

Sample Dates		Age Class 1.1	1.2	2.2	3.2	1.3	2.3	1.4	Other	Total
6/ 1 - 6/15	Numbers	0	13	273	10	64	127	0	3	490
	Percent	0.0	2.7	55.7	2.0	13.1	25.9	0.0	.6	
6/16 - 6/30	Numbers	4	56	702	5	115	186	0	14	1082
	Percent	.4	5.2	64.9	.4	10.6	17.2	0.0	1.3	
7/ 1 - 7/15	Numbers	6	12	230	3	36	17	0	8	312
	Percent	1.9	3.8	73.7	1.0	11.5	5.5	0.0	2.6	
7/16 - 7/30	Numbers	1	2	8	0	3	3	0	0	17
	Percent	5.9	11.8	47.1	0.0	17.6	17.6	0.0	0.0	
Totals	Numbers	11	83	1213	18	218	333	0	25	1901
	Percent	.6	4.4	63.8	.9	11.5	17.5	0.0	1.3	